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(54) Title: SEWER FLOW MONITORING METHOD AND SYSTEM

(57) Abstract: A method and system for monitoring and analyzing flow in a sewer system includes the steps o using a monitoring assembly to collect data representative of actual flow volume of a fluid substance in a first location such as a sewer pipe, storing the actual flow volume data in a memory, maintaining previously stored data in the memory, determining a predicted flow volume and comparing the actual flow volume with the predicted flow volume to yield a difference value. The predicted flow volume is dependent on the data selected from the previously stored data and a day and time that corresponds to both the actual flow volume data and the data selected from the previously stored data. The predicted flow volume may also be dependent upon additional data corresponding to a rain event. When the difference value exceeds a predetermined variance value, the method may further include the step of issuing a flow loss notification. In the difference value does not exceed a predetermined variance value, the method may also include storing the actual flow volume in the memory as stored calibration data. The method may also include the step of transmitting the flow velocity data, depth data, and/or the actual flow volume over a data network such as the Internet to a computing device. The actual flow volume may be represented as a rolling average flow volume.

SEWER FLOW MONITORING METHOD AND SYSTEM

BACKGROUND OF THE INVENTION

Cross-Reference to Related Applications

[0001] This application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application Serial No. 60/274,839, entitled "Sewer Flow Monitoring Method and System", filed March 9, 2001, the contents of which are incorporated herein by reference.

Field of the Invention

[0002] The present invention relates generally to sewage flow monitoring systems. More particularly, the present invention relates to a method and system of monitoring the flow of a fluid substance to detect flow loss based on a predicted flow volume.

Description of the Related Art

[0003] Fluid flows in pipes and open channels are common in numerous industrial, commercial, municipal, and residential systems. Proper and efficient operation of these systems, and meaningful planning for future expansion and maintenance of such systems, depends upon accurate measurement of the flow that passes through such systems. Sewer systems, such as municipal sanitary sewer systems, are an example of one system in which accurate flow measurement is critical.

[0004] Many sewer flow measuring devices operate by detecting both the depth of flow in a channel or pipe and the velocity of the flow in the same location of channel of pipe. The data is collected at periodic sampling times and is used to calculate a flow rate. Examples of such flow measurement devices are disclosed in U.S. Patent No. 4,397,191, to <u>Forden</u>; U.S. Patent No. 4,630,474, to <u>Petroff</u>; and U.S. Patent No. 5,198,989, to <u>Petroff</u>,

each of which is incorporated herein by reference in its entirety. In the wastewater industry, real-time detection of problem events and accurate prediction of future system operation have become increasingly important. Real-time detection of system problems, such as leaks or system breaks, sanitary sewer overflows, and system blockages, allows system managers to quickly respond to such problems. With a rapid response, system managers can prevent or minimize unwanted incidents such as basement back-ups or sewage in waterways that may result from system overflows or breaks. For example, with early detection of a system blockage, managers could respond to and clear the blockage or repair the pipe before it causes an overflow or a buildup of pressure within the system resulting in a break or leak. Further, if an overflow occurs, such as may happen during a storm event, system managers can take action to redirect the flow to other channels within the system in order to reduce or eliminate the overflow condition.

[0005] Further, a system with predictive capabilities could allow managers to stop overflows before they occur, to more effectively use existing system features, and identify and plan for required system expansions.

[0006] Conventional monitoring systems have exhibited several problems. The conventional systems are limited to reporting of data and basic alarming. Such systems do not reliably validate, in real time, monitored data. Further, alarm conditions are typically triggered based on predetermined levels, and the monitoring systems are susceptible to false alarms during storm conditions, holidays, and other unusual events that are not necessarily reflective of a sewer system problem. Further, the conventional monitoring systems lack reliable predictive capabilities for predicting flow at various points in a sewer system.

[0007] Accordingly, it is desirable to provide an improved method and system for monitoring flow in a sewer system.

SUMMARY OF THE INVENTION

[0008] It is therefore a feature and advantage of the present invention to provide an improved flow monitoring method and system.

[0009] In accordance with one embodiment of the present invention, a method of monitoring and analyzing flow in a sewer system includes the steps of using a monitoring assembly to collect data representative of actual flow volume of a fluid substance in a first location such as a sewer pipe, storing the actual flow volume data in a memory, maintaining previously stored data in the memory, determining a predicted flow volume and comparing the actual flow volume with the predicted flow volume to yield a difference value. The predicted flow volume is dependent on the data selected from the previously stored data and a day and time that corresponds to both the actual flow volume data and the data selected from the previously stored data. Optionally, the predicted flow volume may also be dependent upon additional data corresponding to a rain event.

[0010] In situations where the difference value exceeds a predetermined variance value, the method may further include the step of issuing a flow loss notification. If the difference value does not exceed a predetermined variance value, the method may also include storing the actual flow volume in the memory as stored calibration data. As additional options, the method may include the additional step of transmitting the flow

velocity data, depth data, and/or the actual flow volume over a data network such as the Internet to a computing device. Also optionally, the actual flow volume may be a rolling average flow volume.

[0011] As additional options, at least one of the determining step and the comparing step may be performed by the monitoring assembly. In the alternative, the determining step and/or the comparing step may be performed by the computing device. As a further option, the method may include the additional step of validating the data representative of flow velocity and depth. In such a case, the validating step may optionally be performed by the monitoring assembly. In addition, the data representative of actual flow volume may include at least one of flow velocity data and depth data, and the method may include calculating the flow volume based upon such data.

[0012] In accordance with an additional embodiment of the present invention, a flow monitoring system includes a first monitoring assembly having at least one sensor. The sensor operates to collect data representative of actual flow volume at a first location. The system also includes a processor and a memory. The memory operates to store the data representative of flow volume as well as a detection time associated with the data. The system also includes a central computing device in communications with the first monitoring assembly. The processor is trained to compare the actual flow volume with a predicted flow volume to yield a difference value. The predicted flow volume is dependent on the data stored in the memory and the detection time associated with such data.

[0013] Optionally, the processor is further trained to issue a notification if the difference value exceeds a predetermined variance value. Also, the data representative of actual flow volume may include depth data and/or velocity data, and the processor would be further trained to calculate the actual flow volume corresponding to such data.

[0014] As an additional option, the processor may be integral with the first monitoring assembly. As an alternative option, the processor may be integral with the central computing device.

[0015] Also in accordance with this embodiment, a first monitoring assembly may optionally be capable of validating the flow velocity in depth. As an additional option, the system may include a second monitoring assembly that has a means for detecting the quantity of rain at a location during a period of time, such as a rain gauge, a weather service, or even a weather web site. Further, the central computing device may be trained to predict an anticipated flow velocity, depth, and/or flow volume of the fluid substance at a second location.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a flow chart illustrating the steps that may be followed in an embodiment of the present invention as a method.

[0017] FIG. 2 illustrates an example of the operation of the flow loss detection feature of the present invention.

[0018] FIG. 3 further illustrates the flow loss detection feature.

[0019] FIG. 4 further illustrates the flow loss detection feature.

[0020] FIG. 5 illustrates examples of certain hardware aspects of the present system.

[0021] FIG. 6 is an exemplary scatterplot hydrograph in a normal pipe.

[0022] FIG. 7 is an exemplary scatterplot hydrograph in a blocked system.

[0023] FIG. 8 is an exemplary scatterplot hydrograph in a system experiencing sanitary sewer overflow.

[0024] FIG. 9 is a block diagram that illustrates data validation features of the present invention.

[0025] FIG. 10 is a block diagram that illustrates alarm event detection features of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The present invention provides a novel sewer flow monitoring method and system. A flow chart 100 of the present invention in a method embodiment, and the

potential steps to be implemented by a system embodiment, are illustrated in FIG. 1. Referring to FIG. 1, the method includes the step of using a monitoring assembly to collect 12 data representative of flow velocity in depth of the fluid substance in a first sewer location. This data may be collected by velocity and depth sensors that are integral with the monitoring assembly, such as those described in col. 2 of U.S. Patent No. 4,397,191, to Forden (including the drawings referenced therein), and col. 2 of U.S. Patent No. 5,821,427, to Byrd (including the drawings referenced therein), each of which is incorporated herein by reference.

[0027] The method also includes determining a flow volume 16 corresponding to the flow velocity and depth detected. The flow volume may be determined by any appropriate method, such as simply by multiplying the flow velocity and the depth to result in a volume, or by using methods that consider additional variables such as temperature as described for example in U.S. Patent No. 5,198,989, to Petroff, which is incorporated herein by reference in its entirety.

[0028] The steps of detecting a flow velocity and depth and determining a flow volume are preferably performed in the monitoring assembly itself. In such an embodiment, the monitoring assembly would include a processor and a memory, and the processor would be trained, such as through computer program instructions or digital logic, to perform the calculation of flow velocity. Optionally, the flow velocity and depth data may be transferred to a remote or central computing device over a communications network such as the Internet,

and the determination of flow velocity may be performed by the remote or central computing device. The processes of detecting flow velocity and depth and calculating flow volume are periodically repeated, such as may occur during one-minute intervals, fifteen-minute intervals, or any regular or irregular interval that is desired. The flow velocity data, depth data, and flow volume data are stored in a memory 18. In the embodiment where the flow volume is determined at the monitor level, the memory 18 is preferably integral with the monitor. In the embodiment where the flow volume is determined at the computer, the memory 18 is preferably integral with the computer. The memory 18 maintains stored data 20 over a period of time, although optionally data may be discarded after it achieves a predetermined age, such as a week, a month, a year, or (such as many be desirable for data relating to unique days such as holidays) several years.

[0029] As an additional option, in step 12 only one of flow velocity and depth data may be obtained. For example, flow volume could be calculated as a function of either depth or velocity, without need for collecting the other data item. Further, in an optional embodiment, step 12 may be completely eliminated and the system may directly collect flow volume data, such as when data from a pump station or other area is available.

[0030] Optionally, the method may include validating 14 the flow volume and/or depth data before determining the flow volume, or it may include validating 14 the flow volume data after it is determined or calculated. In a preferred embodiment, using depth data for purposes of discussion, the validation is performed by comparing the detected depth

with previously-collected depth data stored in the memory. The validation step considers the time that the data is collected, and preferably the day that the data is collected, and compares it to data previously collected for similar days and times. For example, the system may collect depth data at 8:00 a.m. on a weekday, and the validation step will include comparing that data to depth data collected at or near 8:00 a.m. on previous weekdays. Similarly, weekend days may correspond, and the system may also optionally be programmed to recognize, holidays (which typically have unique flow trends) and/or individual days within the week, such as Mondays, Tuesdays, etc.

[0031] The comparison may be done to the most recent relevant previously-collected data, or it may be to a set of previous data. Preferably, the previously-collected data is limited to that collected recently, such as during the past ten related days and times, so that trends are followed and gradual changes do not result in false determinations of invalidity. Optionally, the previously-collected data may be averaged, or a mean may be calculated for comparison purposes. Optionally, the average may be a weighted average, such that the most recent data is given the most weight, while older data is given less weight. If the current depth data differs from the previous data by more than a predetermined variance level, then the system assumes that the data is invalid, and the monitor is re-fired to collect another set of data. The predetermined variance level may be any amount, such as a percentage or a set number, and is preferably set to be large enough to avoid false invalidity determinations and small enough to capture most invalid readings. After re-firing, the system may perform the validation step again. Optionally, if a predetermined number of re-

firings yield similar results, the system will presume that the data is valid.

[0032] Preferably, the validation step is performed at the monitor level, but optionally and alternatively the validation may be performed by the remote or central computer.

[0033] Returning to FIG. 1, the system includes the feature of detecting flow loss by comparing the actual, detected flow volume with a predicted flow volume. First, the system determines a predicted flow volume 22 based on the data representative of flow velocity and depth in that is previously stored in the memory. As with the validation feature described above, the predicted flow volume is determined based on the day and time of the current reading and comparing 24 it with readings taken at previous, related days and times. If the current reading falls below a predetermined threshold 26, such as 75% of the expected reading, an alarm may be issued 28.

[0034] An illustration 200 of such a comparison is shown in FIG. 2, where the calculated velocity 205 is identified as Q_C and the predetermined threshold 210, such as 75% of the predicted flow loss, is identified as Q_{MIN}. Q_C and Q_{MIN} typically vary over different days and times, as sewage flow on weekdays typically differs from that on weekends, and flows during different times of day also vary. For example, flows at 3:00 a.m. on a weekday are typically much lower than flows at 8:00 a.m. on a weekday. Trends associated with holidays or individual days may also be considered. As illustrated in FIG. 2, if the flow 205

drops below the predetermined threshold 210, an alarm is triggered 215. The alarm, as well as any or all of the data, may be transmitted to a remote or central computer over a communications network, as illustrated by step 30 in FIG. 1.

[0035] FIG. 3 illustrates that the method may include compensation for wet weather. For example, FIG. 3 illustrates that when the system detects a gradual increase in flow volume or a gradual decrease in flow volume, the system may presume that the increase or decrease results from a storm event. In such a situation, a quick loss is identified 305 as an actual flow loss, while a gradual decrease is identified as an end of a storm event. Optionally, the system may use actual data collected from one or more rain gauges, or even data obtained from a weather service or weather web site, to determine when a storm event is occurring.

[0036] FIG. 4 illustrates that the predetermined threshold 210 is preferably set at a level that is not too close to the actual readings in order to avoid false alarms. For example, starts and stops of pump stations in a sewer system can cause spikes and/or erratic flows 405. Thus to avoid a change and pump status causing a false alarm, the predetermined threshold 210 may be anywhere from 5% to 50% below the predicted value, or more or less as may be appropriate for the system. In addition, to avoid "spikes" 405, the actual flow volume 205 may be calculated on a "moving boxcar" or rolling average basis, such as by using the average of the previous two, ten, or any predetermined number of readings.

[0037] FIG. 5 illustrates an example of several elements of the system embodiment 500 of the present invention. Referring to FIG. 5, a network of flow monitors 505 detects depth and velocity at various locations in a sewer system. The monitors 505 communicate with a central or remote server 510 over a data network such as a local area network, wide area network, or the Internet. Optionally, the central server 510 may also communicate with one or more user workstations 515 over a data network such as a local area network, wide area network, or the Internet. The system 500 may also be used to monitor or predict potential problems with a sewer system.

[0038] During the last century, several hydraulic engineers developed equations, known as pipe curve equations or hydraulic element curves, to describe the relationship between the depth of open channel gravity flow to the velocity of that flow. For a given depth of flow there is a unique and predictable velocity (and flow rate). Figure 6 shows an exemplary scattergraph 600 from a normal open channel flow sewer. The plot of paired depth and velocity readings from an open channel flow meter should form a pattern similar to this pipe curve 600. Patterns that deviate from the expected pipe curve 600 indicate that either the hydraulics of the pipe are changing or the meter is malfunctioning.

[0039] It is a rare sewer system that produces an ideal scattergraph 600. Bottlenecks can be caused by undersized pipes, broken pipes, roots and severe turns in manholes. Figure 7 illustrates the classic "ski jump" shape 700 which is the distinguishing characteristic of a sewer with a downstream bottleneck. The hydraulic grade line 700 in this example will

become flat during the surcharge period and the backwater condition can be detected several manholes upstream of the bottleneck.

[0040] Sanitary sewer overflows (SSOs) are also a problem in many sewer systems. They are difficult to witness or document because they usually occur during rain events when people are indoors. Also, they frequently are located out of sight at the lowest manholes or structures along creeks and ravines. Toilet paper in the branches along the creek may be the only evidence that some SSOs leave behind. The first reaction to SSO's from casual observers and some collection system managers may be that they "need a bigger pipe." However, in whole or in part, many SSOs are caused by a downstream bottleneck. Thus, in such cases, bigger pipes may not be needed, and simple elimination of the bottleneck may solve the problem. SSOs and bottlenecks each will leave telltale evidence in the data of nearby flow meters. Figure 8 is an exemplary scattergraph 800 produced by flow monitor data collected during an upstream SSO event.

[0041] Referring to FIG. 9, a block diagram 900 illustrates how the present inventive method 100 and system 500 can use scatterplots to validate data and identify bottlenecks and SSOs. An optional "scatterplot feature" 905 compares valid depth and velocity data points to an expected hydraulic signature curve. If these data points do not fall within the expected hydraulic signature curve limits, the sensors are re-fired to collect new data at block 910 to test the validity of the data and verify whether a sensor may have malfunctioned. If depth and velocity data points are repeatable, it is assumed that the data is valid and it is stored.

If they are not repeatable, they are flagged as "bad" data. If the verified data points fall outside of expected curve limits, the alarm notification module 915 initiates an event call out. An optional "hydrograph function" 920 compares valid depth data with previously-collected data, such as a "learned 24 hour" diurnal curve. The result of that comparison typically indicates a quantity above or below the expected diurnal curve at a specific time of day. Any quantity plots above or below the expected diurnal curve may result in an alarm event at block 915.

[0042] FIG. 10 is a block diagram 1000 that illustrates exemplary embodiments of features of event management in the present inventive method 100 and system 500. Upon receiving an event notification 1003 from a flow monitor 505, the system 500 may plot the event depth and velocity points against an expected hydraulic signature curve at block 1005. The expected hydraulic signature curve is generated using a 24 hour data collection, followed by analysis and normalization of the data at block 1008. If the event depth and velocity points fall inside a normal plot standard deviation, the system 500 considers the point to be valid. The system 500 may also plot the event depth points against an average weekday or weekend or holiday hydrograph at block 1010. Data is then saved in an event management store at block 1015. If an event depth point falls above or below the predetermined average daily hydrograph limits, the system 500 considers the event depth point to be invalid and may trigger an alarm and/or recollect the data at 1020. Optionally, if a predetermined number of alarms occurs in a set period (such as three alarms in an eight-hour shift), a high priority alarm may be triggered at 1020 in order to prompt a user of

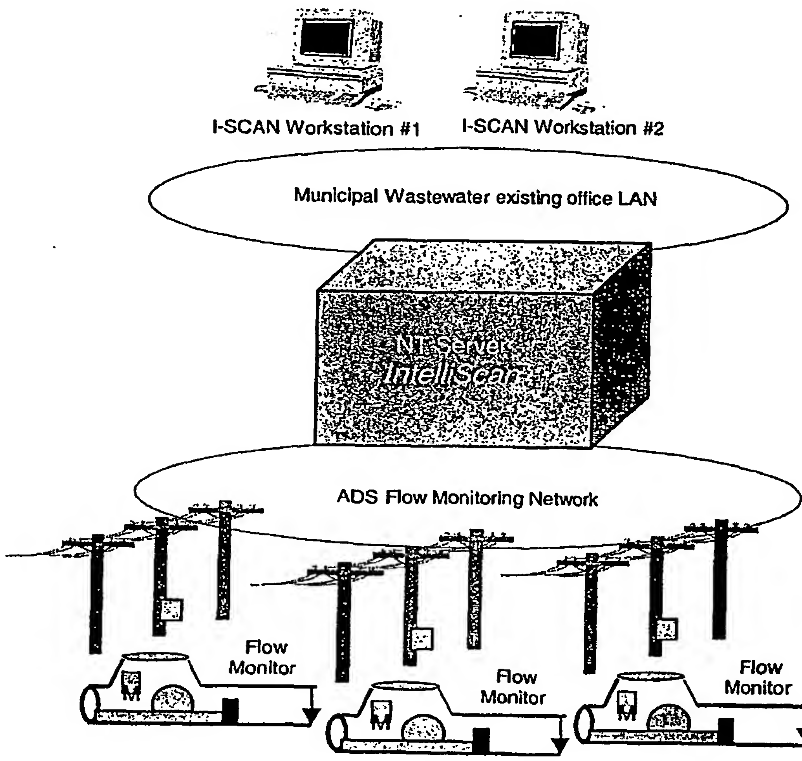
system manager to investigate the problem.

[0043] The system 500 includes several functions that a user may optionally see on a user display. For example, a log-on/log-off button may be provided to allow the user to log on and off the system. A system overview button may allow the user to select a graphic view of the system that provides an overview of a geographic area, such as a county or river basin. The user may be provided with a select topic button that allow the user to select an area, such as a county or basin, or an individual site. Alarm summaries and communications summaries may also be made available to the user. Optionally, a weather button may allow the user to view weather data, such as that collected by rain gauges or even as obtained from a weather service or weather web site. A site detail screen may allow the user to see real-time monitor data as well as scatterplots and time-lapse data. Such data may include, for example, flow volume, velocity, and depth, temperature, pH, or even content such as dissolved oxygen. Further examples of such screens and plots are described in the materials appended hereto, and made a part hereof, as Appendix A.

[0044] It is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth herein the following or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract included below, are for the purpose of description and should not be regarded as limiting.

APPENDIX A

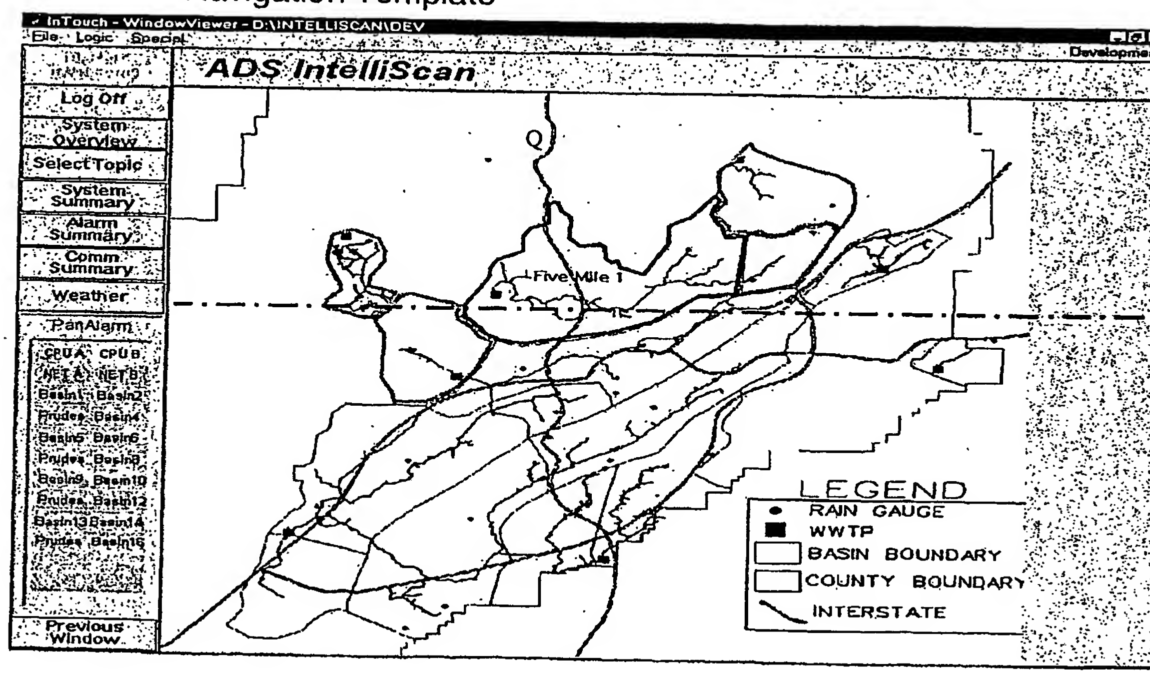
Network Plan Schematic



1.0 Display / Report Plan

The ADS Intelliscan FMAS, utilizes an object oriented, Graphical User Interface (GUI) based on Wonderware Intouch and the Microsoft NT 4.0® standard. This allows Intelliscan to scan and log remote flow sites, and gives the user the ability to visualize and analyze flow data graphically. The Intelliscan GUI is comprised of several components that provide visualization, historical trending, event handling, alarm logging, reporting and analysis tools. These features combine to create a complex and powerful operator interface, providing a point and click environment for ease of use. The following screen displays explain functionality associated with each particular screen in greater detail.

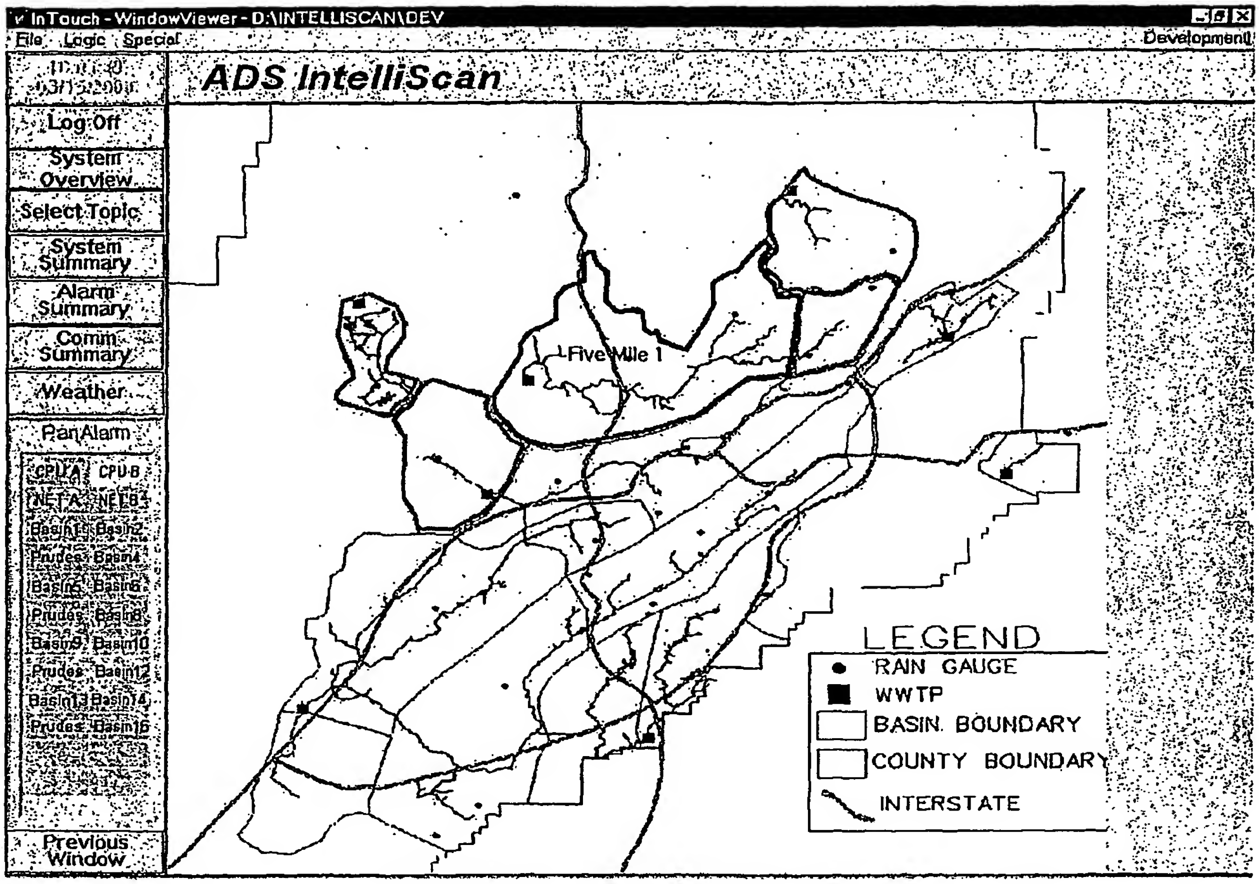
1.1 Navigation Template



Navigation Template- located on left hand side of each screen

- ***Log On / Log Off*** button allows the user to Log On and Log Off of the Intelliscan system
- ***System Overview*** button selects a county overview screen
- ***Select Topic*** button brings up a Select Topic window for Basin or Site selection
- ***Alarm Summary*** button brings up the Alarm Summary screen
- ***Comm Summary*** button brings up a Communications Summary screen
- ***Weather*** button brings up an internet browser with weather web site connectivity.

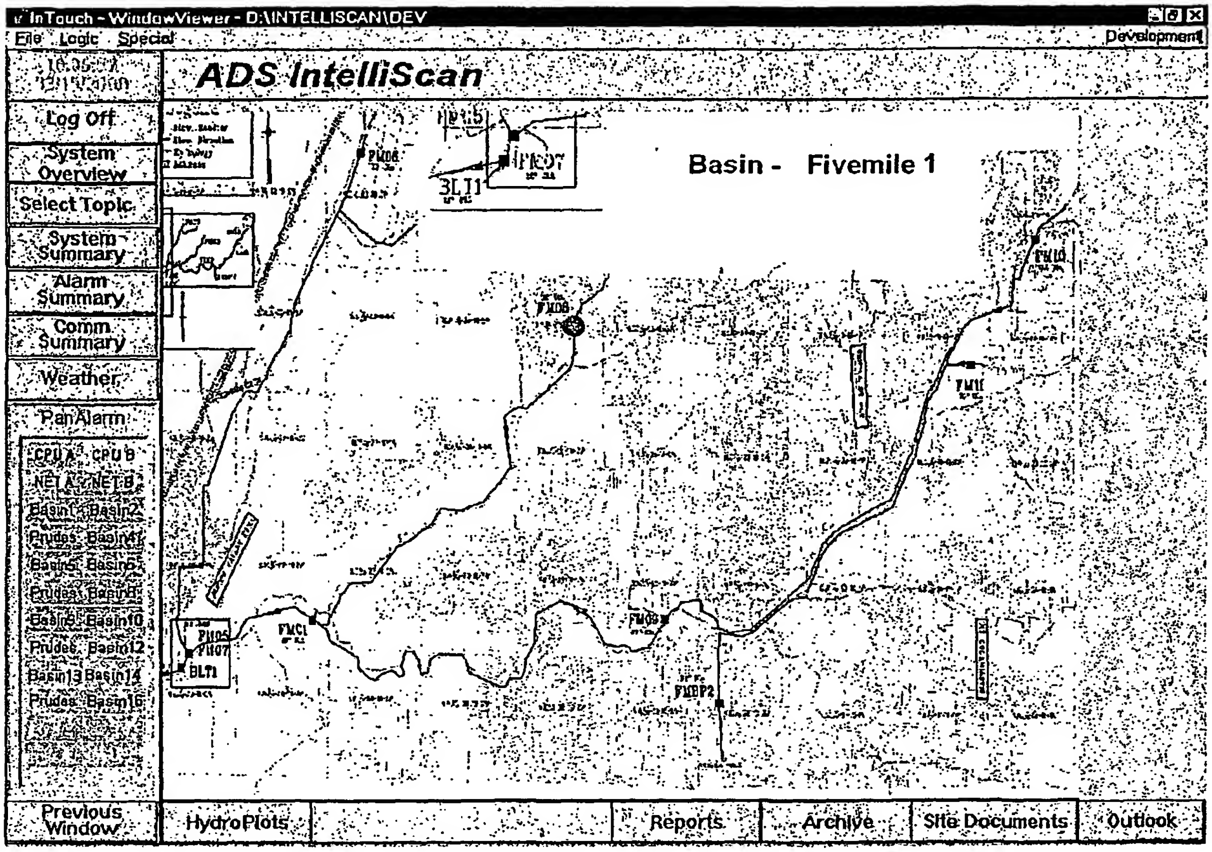
2.2 County Map Overview Screen



County Map Overview-

- This is the screen that is displayed upon initially logging into the Intelliscan system
- Provides an overview of all Basins in county
- Basins with ***Green*** outline indicate all sites within that Basin are within normal operating ranges
- Basins with flashing ***Red*** outlines indicate a site within in that Basin has an unacknowledged alarm
- Basins with solid ***Red*** outlines indicate that a site within that Basin has an acknowledged alarm
- Clicking on a particular Basin will bring up a ***Basin Overview*** screen

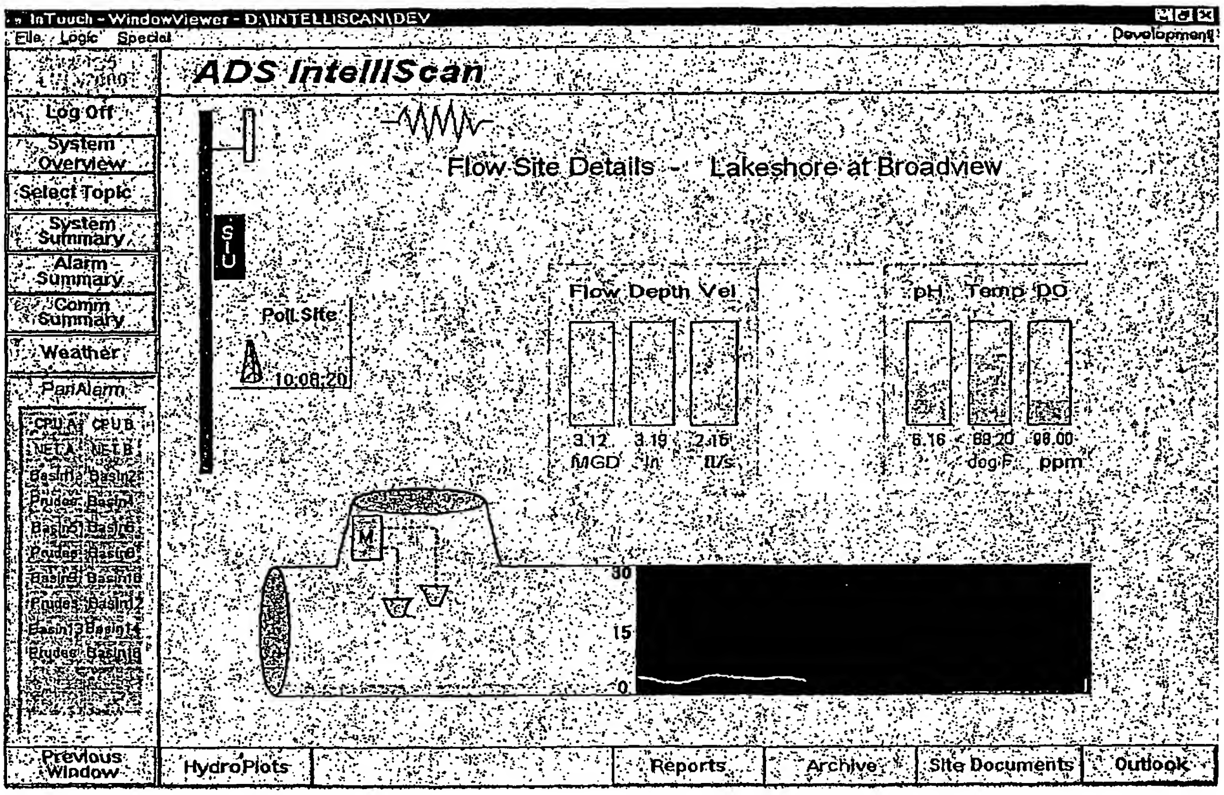
2.3 Basin Overview Screen



Basin Overview-

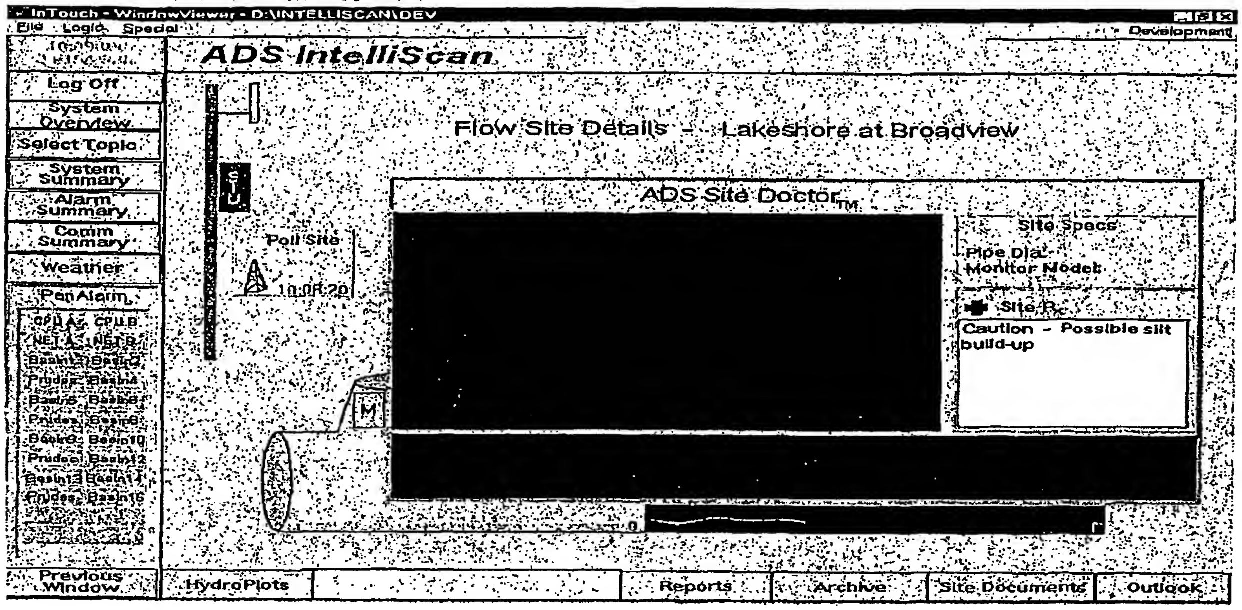
- Provides a map showing each Flow Site and its status within a Basin. The operator can click on any of these active sites and drill down to the specific site detail screen.
- Sites in an unacknowledged alarm condition will flash ***Red***
- Sites in an acknowledged alarm condition will show in solid ***Red***
- ***HydroPlots*** button launches ***HydroPlot Screen*** for ad hoc plotting
- ***Reports*** button launches the Report menu with options to select specific reports for view, edit or creation.
- ***Archive*** button launches a menu of databases for selection, view and editing.
- ***Documents*** button launches a document menu for document selection, view and edit.
- ***Outlook*** button launches Microsoft Outlook for E-Mail and other office functions.

2.4 Site Details



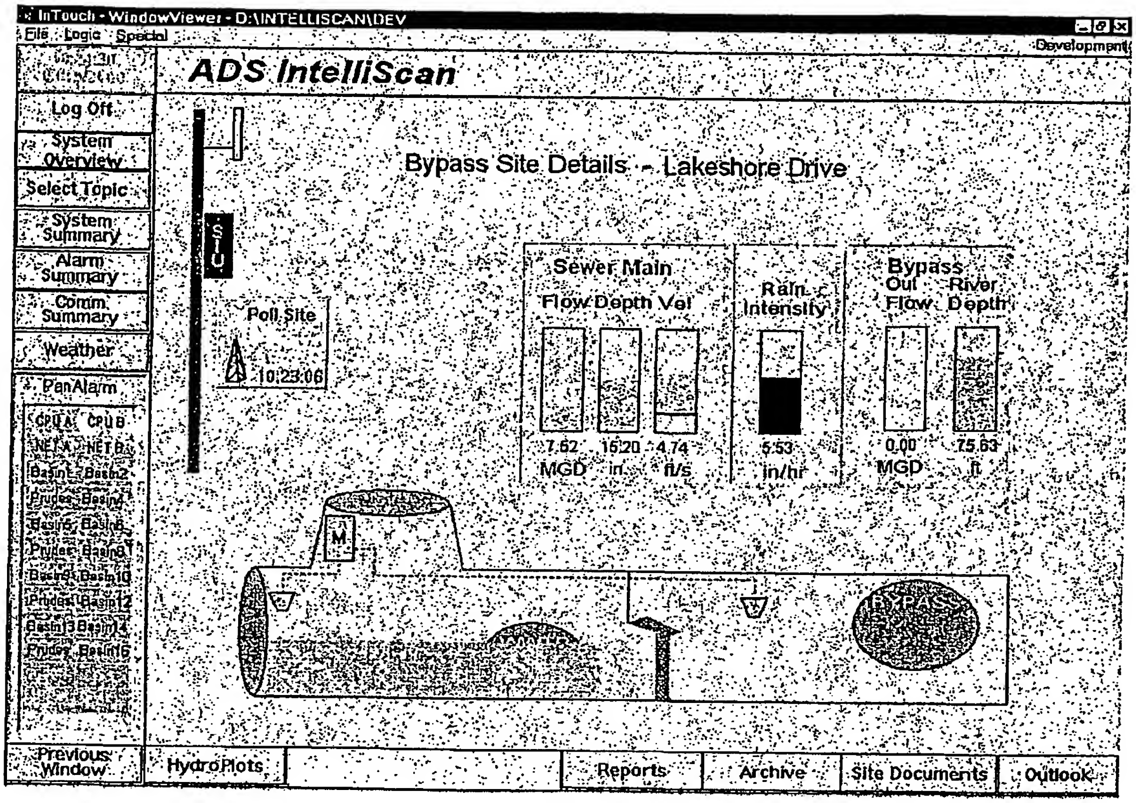
- Selection of a site icon while in the ***Basin Overview*** screen displays the specific ***Site Detail Screen.***
- The ***Site Detail*** screen provides real time information about a specific site as well as a 24 hour site HydroPlot
- ***Flow/Depth/Vel* sliders** and integers provide site data from the most recent polling activity.
- ***pH/Temp/DO Sliders and Integers*** provide pH, Temp and Dissolved Oxygen Information from the site if implemented. *Note: These Environmental Sliders will remained hidden unless the site selected is instrumented for these readings*
- ***Poll Site*** button launches a demand polling of the site. Upon initiation of a demand poll, a telemetry icon will travel across the top of the screen indicating telemetry system activity at that site. The Flow, Depth and Velocity values are returned from the monitor and displayed on the sliders and integers graphics.
- A graphical image of a sewer line with flow instrumentation is shown on the screen. This image provides current site depth visualization, alarm condition and contains a Hydroplot showing the last 24 hours of site information.

2.5 Site Data Review



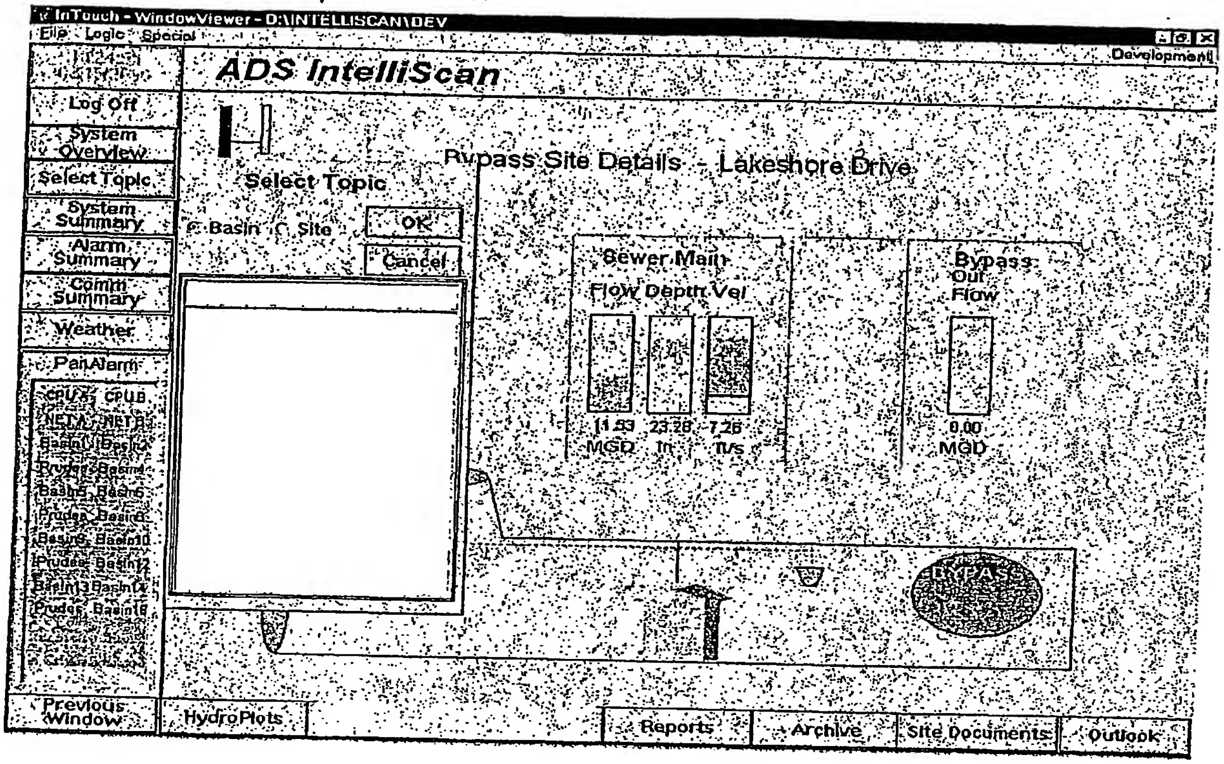
- Clicking on the Manhole Cover while in the ***Site Detail*** screen displays ***Site Data Review***. ***Site Data Review*** screen provides the user with a thumbnail sketch of the flow performance and changing hydraulic conditions at each site. It also helps the user to assess flow monitor instrument health condition by displaying good points, flagged bad points and flow monitor battery health.
- A ***Site Data Review*** window will be displayed with two scatter plots and one hydroplot.
  -***Scatter plot #1*** will display the relationship of site depth verses velocity. This site flow performance indicator is for the last 24 hours. This plot will contain good data points in green and flagged bad data points in red with a "Lease Squares Curve Fit" line.
  -***Scatter plot #2*** will display three "Lease Squares Curves" without the data points. Scatter plot #2 will display changing site hydraulic conditions comparing 24 hours ago with 48 hours ago and the month's average.
  -***The Hydroplot*** display will show a graph of sewer depth for seven days.
  These plots can be used to analyze site hydraulics and performance.
  - ***Site pipe specifications*** will also be displayed in a Site Data Review window for dimensional and correction factor references plus battery voltage.

2.6 Bypass Site Detail Screen



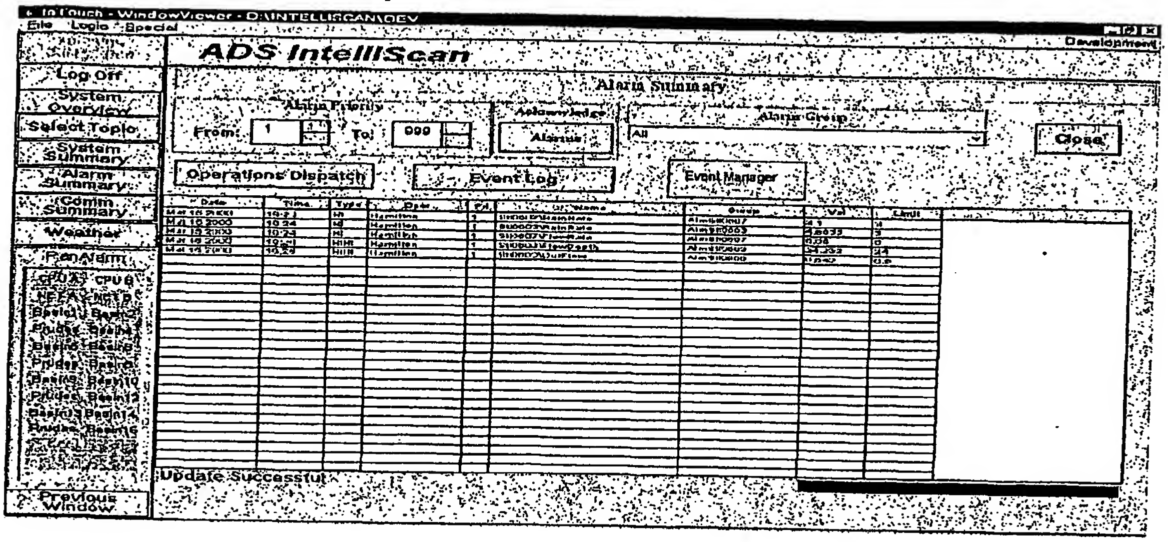
- While in the ***Basin Overview*** screen, selection of a ***Bypass Site*** will bring up the ***Bypass Site Detail Screen.***
- 3 graphics will be displayed:
  -The first graphic will display sliders and integers reflecting the real time condition within the Bypass Vault. These include flow rate, depth and velocity
  -The second graphic displays current rain activity as defined by any atAUCShed associated Rain Gauge
  -The third graphic displays the Bypass Outflow Rate and current River Depth if a stream gauge is atAUCShed
- A graphical display of the Bypass Site providing sewer main depth in relation to the Weir Wall and flow monitor instrumentation are also displayed
- Clicking on the Manhole Cover while in the ***Site Detail*** screen displays ***Site Data Review.*** The Site Data Review screen will be displayed showing Site Data Review Functions for that site.

2.7 Select Topic Function



- From the ***Navigation Template***, located on the left-hand side of the screen, a ***Select Topic Button*** can be selected to display a topic selection menu.
- This window menu allows the user to view all of the site or basin names that are selectable and allows the user to select either a Site or a Basin for screen display.
- After selecting a specific topic from the menu, the user can either launch the specific topic screen using the "OK Button" or cancel the selection process by selecting the "Cancel Button".

2.8 Alarm Summary Screen

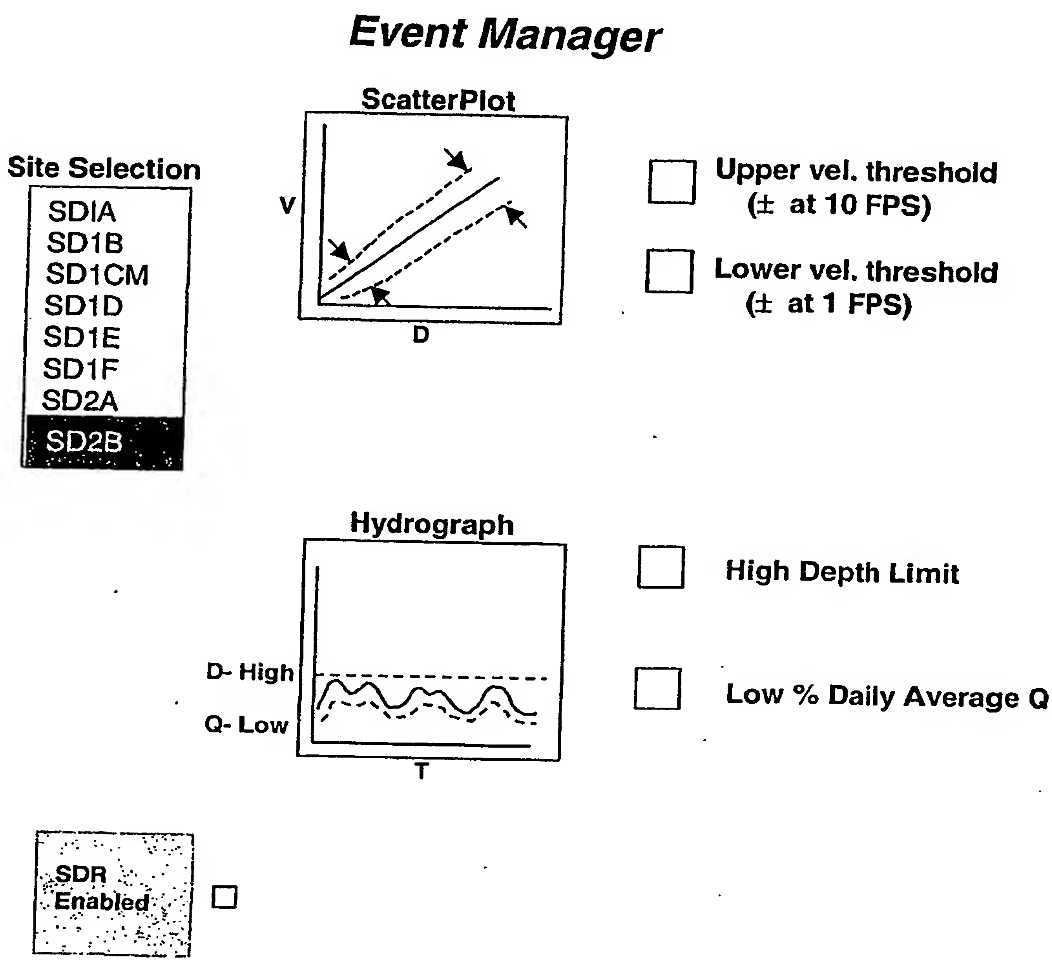


- When the ***Alarm Summary*** screen is selected from the Navigation Template, the ***Alarm Summary Screen*** appears and displays the following:
- **Priority Window** allows user to query Alarms by Priority.
- **Alarm Acknowledge Button** allows the user to acknowledge a selected active alarm.
- **Alarm Group Button** allows the user to query various alarm groups such as Basin or Lift Station Alarm Groups separately.
- **Operations Dispatch Button** allows the user to send a copy of the selected alarm via E-Mail to an operations or maintenance dispatch group.
- **Event Manager Button** displays the Event Manager pop-up window.
- **Event Log Button** allows the user to display the Event Log, which displays a historical summary of all events and alarms to date.

When the ***Alarm Summary*** screen is selected the **IntelliHMI** system will generate an Alarm Summary report and display it upon the screen. This report contains fields that provide the following alarm related information:

-Date of alarm
-Time of alarm
-Type of alarm
-Name of operator logged on whom acknowledges alarm
-Alarm priority
-Alarm name
-Alarm group
-Alarm value
-Alarm limit

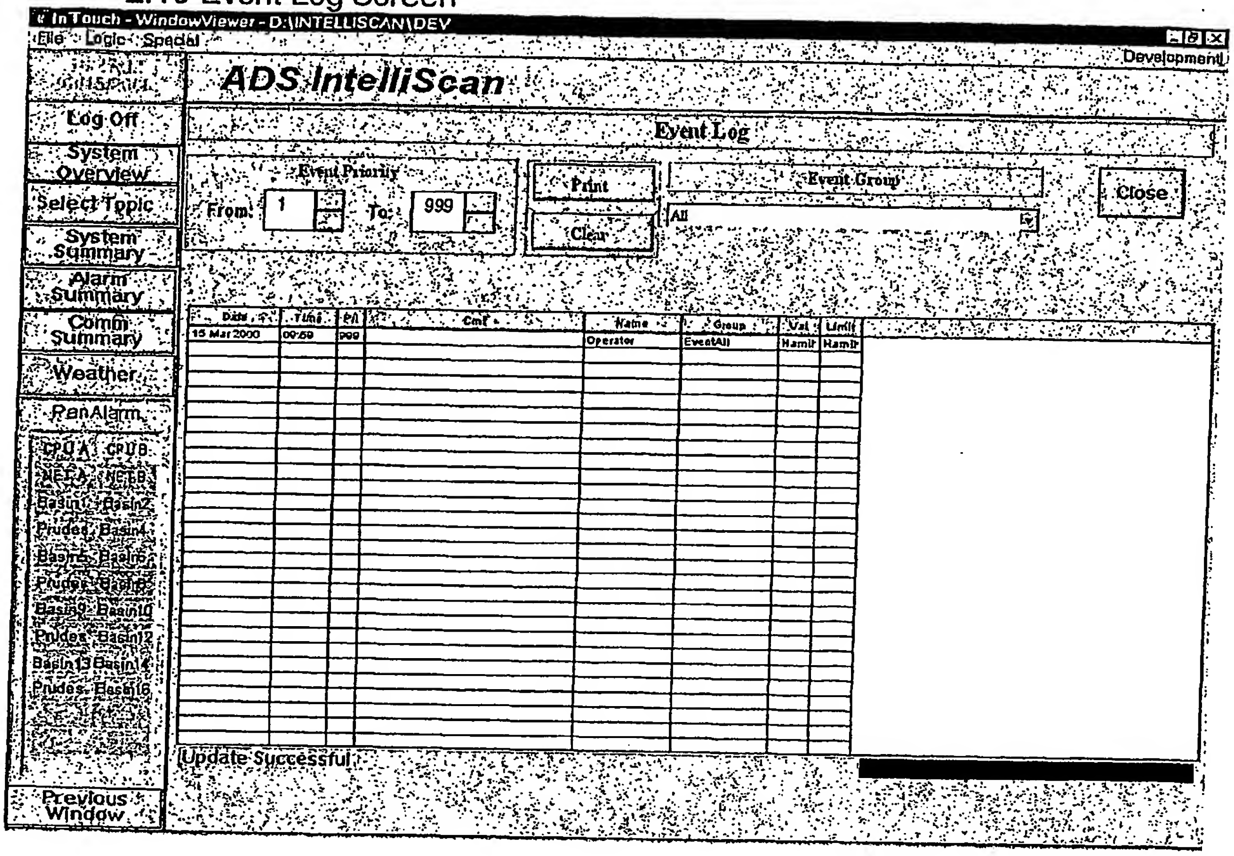
2.9 Event Manager Pop-Up Window



The Event Manager pop-up window provides the user with a point and click environment for:

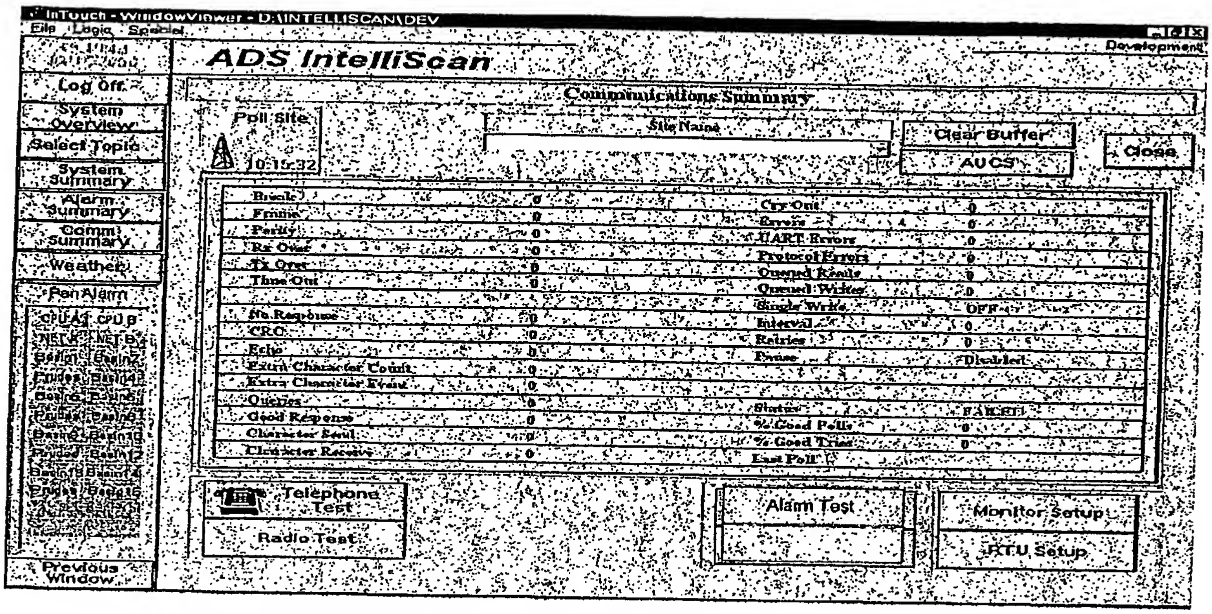
- Setting alarm limits for IntelliScan based alarm functionality
- Enabling/Disabling Site Data Review for specific sites

2.10 Event Log Screen



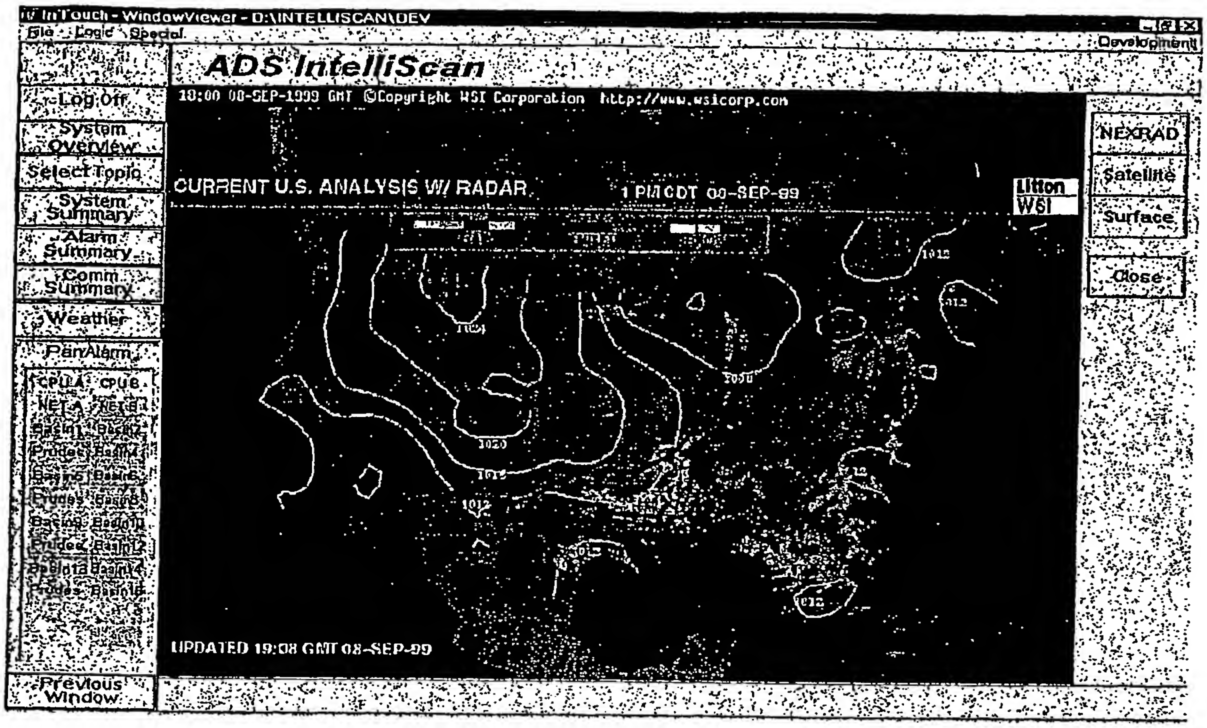
- When the ***Event Log Button*** is selected in the ***Alarm Summary Screen***, the **Event Log screen** is displayed.
- **Event Log Priority Button** allows the user to query events by priority for display.
- **Event Log Group Button** allows the user to query specific event groups for display such as all alarms associated with a specific Basins or Lift Stations.
- **Print Button** is provided to dump the Event Log to a printer on the network.
- **Clear button** is provided to enable clearing of the Event Log with security password.
- When the ***Event Log*** screen is selected the **IntelliHMI** system will generate an Event Log report and display it upon the screen. This report contains field that provide the following event related information:
  -Date of event - Time of event - Event priority - Operator generated comments about the event - Event name - Event group - Event value - Event Limits

2.11 Communications Summary Screen



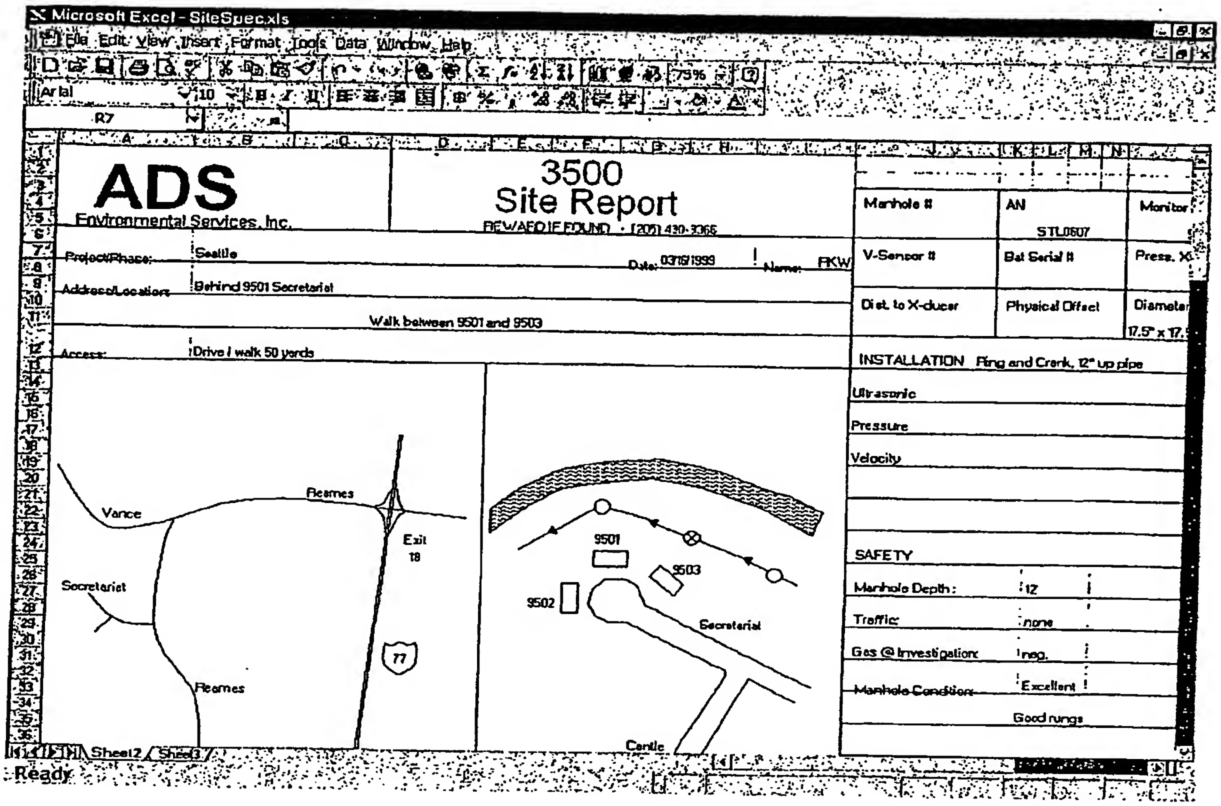
- When the ***Communication Summary*** screen is selected from the ***Navigation Template*** the ***Communication Summary screen*** is displayed.
- This screen provides a pull down summary of telemetry statistics for each site.
- A **Poll Site** button is provided allowing demand polling of the selected site.
- A Clear Buffer button is provided to allow user clearing of the Communication Summary buffer
- An **AUCS** (ADS Universal Communications Server) button is provided allowing access for configuration of AUCS telemetry for each site
- A **Close** button is provided allowing the user to exit the Communication Summary screen
- After a selected site is polled Intelliscan provides a detailed analysis of communication characteristics between Intelliscan and the selected site.
- A **Telephone Test** button is provided to allow testing of phone system attributes for landline communication systems.
- A **Radio Test** button provides for testing of communications to any site connected to Intelliscan via Spread Spectrum Radio.
- An **Alarm** Setup button is provided to allow configuration of the Win911 Paging card.
- A **Monitor Setup** Button is provided to launch ADS QuadraScan for calling the flow monitor for instrument configuration, maintenance and analysis purposes.
- An RTU Setup Button is provided to launch the ADS SCADA Interface Unit configuration and maintenance routine. Note this routine is not currently in the scope of work and will produce a pop-up stating "FUNCTION NOT IMPLEMENTED"

2.12 Weather Map Screen



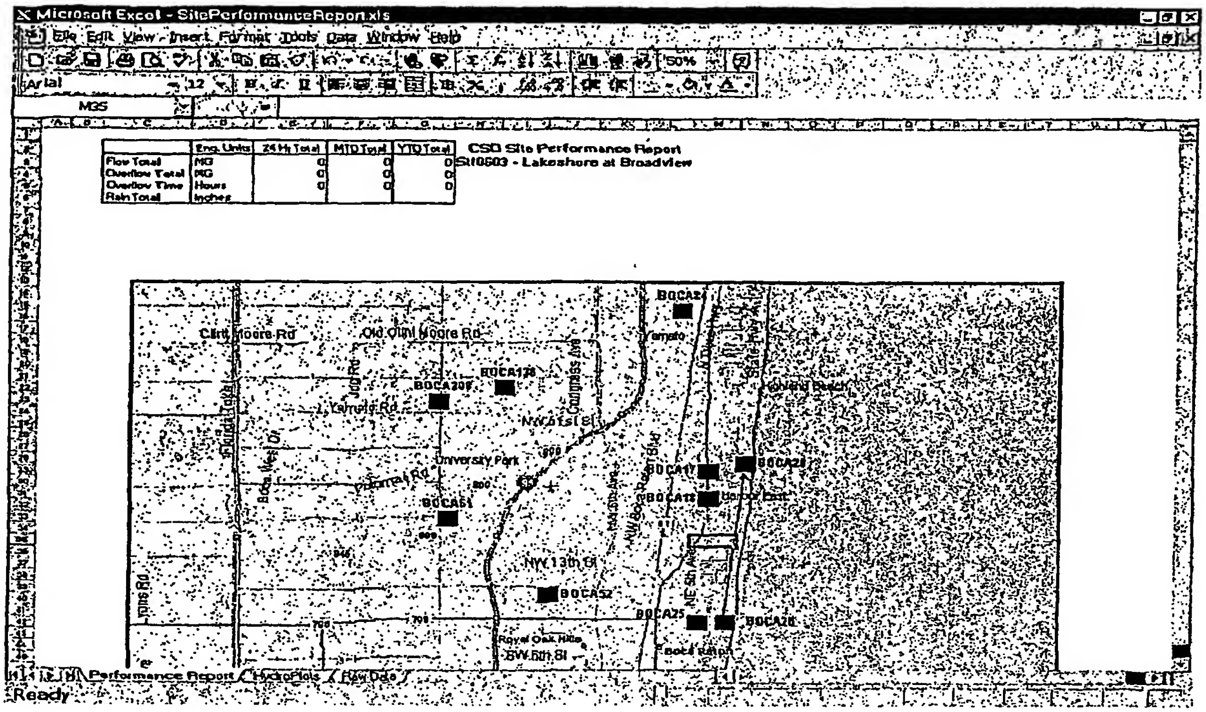
- When the ***Weather*** button is selected form the **Navigation Template,** a Microsoft Explorer Internet Browser screen will be launched within the IntelliHMI application. This browser screen will auto log-on through the City's ISP to IntelliCast.Com. The user will be able to navigate thru IntelliCast weather displays for the local and national region.

2.13 Document Screen



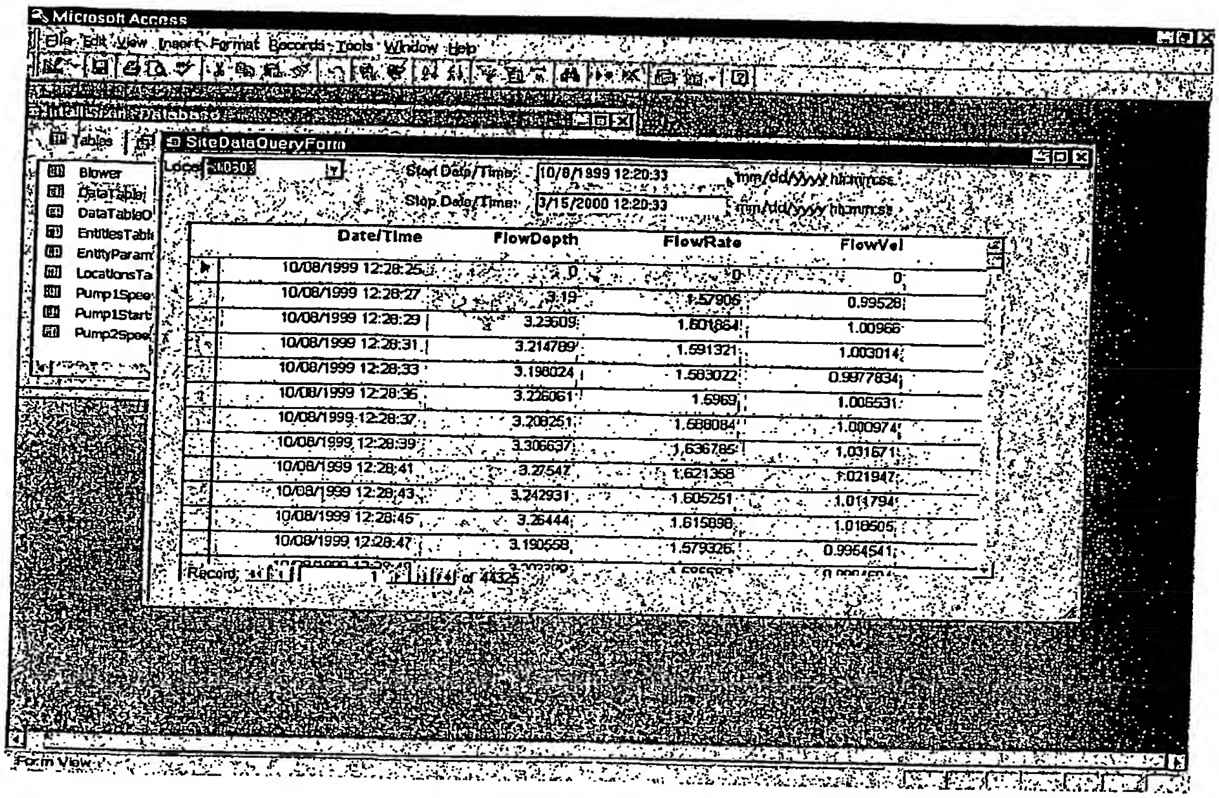
- When the ***Document Button*** is selected from the **Function Bar** (at the bottom of most IntelliScan screens) a Document Menu will appear. The user will be allowed to select from a list of documents and launch specific documents with their editors or viewers.
- The Site Report contains detailed information regarding each specific flow site. This information includes geographical location of the site, monitor type, serial number, installation date, installation details, phone number, ID number, field personnel comments, etc.

2.14 Report Screen



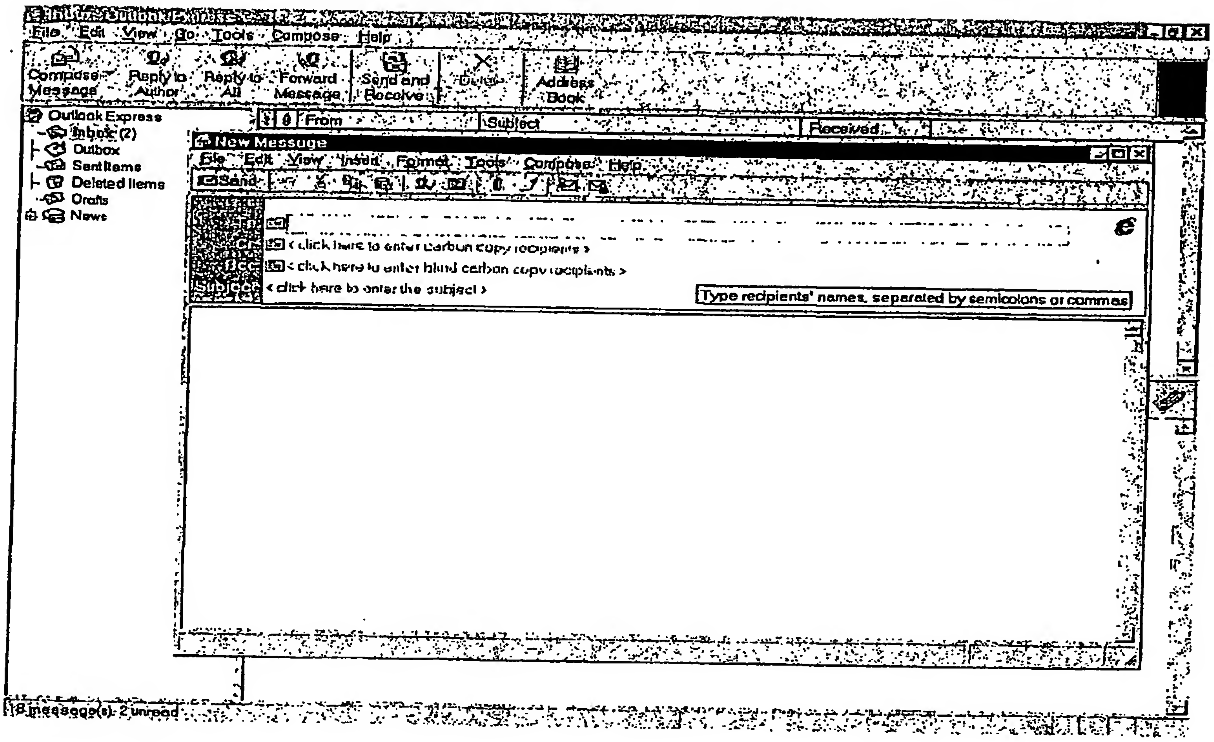
- When the ***Report Button*** is selected from the Function Bar, a menu pop-up of available reports is displayed. The user is allowed to select a report of choice and launch the report with it's Microsoft Excel Editor.
- In the above graphic, a Site Performance Report is launched and the Microsoft Excel editor starts building the report from the ***IntelliSQL Archive / Retrieval System***. Once the report is fully constructed, the user can view the following:
  - **Sheet # 1** – Site flow summary with graphics for last 24 hours.
  - **Sheet # 2** – Site or Basin Summary Plots
  - **Sheet # 3** – Site or Basin Raw Data in Spreadsheet format. Note this data can be edited, selected, copied or even linked to other spreadsheets automatically.

2.15 IntelliSQL Archive / Retrieval System



- When the ***Site Data Query Form*** is selected from the Archive / Retrieval Menu Pop-up, IntelliScan launches the Microsoft Access County Database query editor.
- This ***Site Data Query Form*** provides a pull down menu to select specific site locations for the query, date range and time range to be entered.
- When the Site Data Query is initiated the Archive/Retrieval system is accessed and a report with the following site data is generated;
  - **Site** queried
  - **Date/Time** of query
  - **Flow Depth** at selected site
  - **Flow Rate** at selected site
  - **Flow Velocity** at selected site

2.16 Outlook Screen



- When the ***Outlook function*** is selected from the Function Bar, IntelliScan launches Microsoft Outlook. The user then has full control of Outlooks features for scheduling, phone directories, E-Mail functions and other office like personal productivity tools.

3.0 Archive / Retrieval System

3.1 Overview

The Archive / Retrieval System allows a user, with appropriate access levels, to view and retrieve system data in multiple formats. These formats include but are not limited to alarm history data; minimum and maximum flow data for the entire system, basins or sites; flow data relative to specific times or dates, etc. The Archive / Retrieval System is fully customizable to develop customer specific reports. This feature provides a powerful tool for analysis overall system performance, basin performance, or individual flow site performance.

3.2 Database Structure

The Intelliscan System utilizes a Microsoft SQL® database for Archive / Retrieval functions. This database is OBDC compliant and configured for asynchronous data transfer. Within Intelliscan™, The IntelliCOM module, which facilitates communications with field sites, will be the primary mechanism that populates the database with field information. Site Data Review will also access the database and will populate certain fields during specific Intelliscan™ functions, as well. User access to the Intelliscan™ database is gained through one of two workstations provided.

3.3 Site Data Logging Plan

Intelliscan™ will be accessing over sixty five flow/data sites for The City of San Diego. In addition to demand scans and timed scans of these assets, daily site logging will be accomplished. During site logging the Intelliscan™ server will dial each site within a basin via a modem mux and upload site data into the Archive / Retrieval System. This daily logging activity will be timed and coordinated to occur during minimum system usage hours.

3.4 Report Generation

Intelliscan™ will access the Archive / Retrieval System for report generation. Reports will be displayed in a Microsoft Excel® format. The report generation functions of Intelliscan™ are fully configurable to allow custom reports to be generated to support any user needs. The ability to custom configure data form the Intelliscan™ database and present it in a user defined report structure provides a powerful analytical tool for proactively managing sewer and wastewater assets.

WHAT IS CLAIMED IS:

1. A method of monitoring and analyzing flow in a sewer system, comprising the steps of:

collecting, using a monitoring assembly, data representative of actual flow volume in a first location;

storing the data representative of actual flow volume in a memory;

maintaining, in the memory, previously stored data representative of previous flow volumes;

determining a predicted flow volume, wherein the predicted flow volume is dependent upon data selected from the previously stored data and a day and time, wherein the day and time each correspond to both the data selected from the previously stored data and the data representative of actual flow volume; and

comparing the actual flow volume with the predicted flow volume to yield a difference value.

2. The method of claim 1, wherein the difference value exceeds a predetermined variance value, and the method further comprises the step of issuing a flow loss notification.

3. The method of claim 2, wherein the method further comprises the step of communicating the flow loss notification by at least one of a cellular telephone means, a land line telephone means, a pager, an electronic mail means, and an Internet means.

4. The method of claim 1, wherein the difference value is equal to or less than a predetermined variance value, and the method further comprises storing the actual flow volume in the memory as stored calibration data.

5. The method of claim 1, wherein the step of collecting data representative of actual flow volume includes the steps of:

collecting data representative of flow velocity and data representative of depth; and

calculating the data representative of actual flow volume using the data representative of flow velocity and the data representative of depth, and

the method further comprising the step of transmitting at least one of the data representative of flow velocity, data representative of depth, and data representative of actual flow volume over a data network to a computing device.

6. The method of claim 1, wherein the data representative of actual flow volume includes data representative of a rolling average flow volume.

7. The method of claim 1, wherein the data representative of actual flow volume includes at least one of flow velocity data and depth data.

8. The method of claim 1, wherein at least one of the determining step and the comparing step is performed by the monitoring assembly.

9. The method of claim 1, wherein at least one of the determining step and the comparing step is performed by a computing device.

10. The method of claim 1, wherein the step of collecting data representative of actual flow volume includes the steps of:

collecting data representative of flow velocity of a fluid substance and data representative of depth of a fluid substance; and

calculating the data representative of actual flow volume using the data representative of flow velocity and the data representative of depth, and

the method further comprising the step of validating the data representative of flow velocity and the data representative of depth.

11. The method of claim 10, wherein the validating step is performed by the monitoring assembly.

12. The method of claim 1, wherein the predicted flow volume is further dependent upon additional data selected from the previously stored data, the additional data corresponding to a rain event.

13. A flow monitoring system, comprising:

a first monitoring assembly having at least one sensor, wherein the at least one sensor is operative to detect data representative of actual flow volume of a fluid substance at a first location;

a processor in communication with the first monitoring assembly;

a memory, wherein the memory is operative to store the data representative of actual flow volume and a detection time associated with said data; and

a central computing device in communication with the first monitoring assembly,

wherein the processor is trained to compare the actual flow volume with a predicted flow volume to yield a difference value, the predicted flow volume being dependent upon the data stored in the memory and the detection time associated with said data.

14. The system of claim 13, wherein the processor is further trained to issue a notification if the difference value exceeds a predetermined variance amount.

15. The system of claim 13, wherein the data representative of actual flow volume comprises at least one of velocity data and depth data, and wherein the processor is further trained to calculate an actual flow volume corresponding to the at least one of velocity data and depth data.

16. The system of claim 13, further comprising an alarm device, the alarm device being integral with the processor, and the alarm device being configured to selectively issue an alarm based on the difference value.

17. The system of claim 16, wherein a current threshold value is computed on the basis of the predicted flow volume and the actual flow volume, the current threshold value being updated periodically, and wherein the alarm device is configured to issue an alarm when the actual flow volume is less than the current threshold value.

18. The system of claim 17, wherein when an alarm is issued by the alarm device, the first monitoring assembly is configured to communicate the alarm.

19. The system of claim 18, wherein the first monitoring system is configured to communicate the alarm via at least one of a cellular telephone means, a land line telephone means, a pager, an electronic mail means, and an Internet means.

20. The system of claim 13, wherein the processor is integral with the first monitoring assembly.

21. The system of claim 13, wherein the processor is integral with the central computing device.

22. The system of claim 13, wherein the first monitoring assembly is further operative to detect data representative of flow velocity and depth, and to validate the data representative of flow velocity and depth.

23. The system of claim 13, further comprising a means for detecting a quantity of rain at a location during a period of time.

24. The system of claim 23, wherein the means for detecting a quantity of rain includes at least one of a rain gauge, a weather service, and a weather web site.

25. The system of claim 13, wherein the central computing device is trained to predict at least one of an anticipated flow velocity, an anticipated depth, and an anticipated flow volume of the fluid substance at a second location.

26. An apparatus for monitoring and analyzing flow of a fluid substance in a sewer system, the apparatus comprising:

a first means for monitoring fluid flow having at least one means for sensing, wherein the at least one means for sensing is operative to detect data representative of actual flow volume at a first location;

a means for processing in communication with the first means for monitoring;

a means for storing data, wherein the means for storing data is operative to store the data representative of actual flow volume and a detection time associated with said data; and

a means for computing in communication with the first means for monitoring,

wherein the means for processing is trained to compare the actual flow volume with a predicted flow volume to yield a difference value, the predicted flow volume being dependent upon the data stored in the means for storing data and the detection time associated with said data.

27. The apparatus of claim 26, wherein the means for processing is further trained to issue a notification if the difference value exceeds a predetermined variance amount.

28. The apparatus of claim 26, wherein the data representative of actual flow volume comprises at least one of velocity data and depth data, and wherein the means for processing is further trained to calculate an actual flow volume corresponding to the at least one of velocity data and depth data.

29. The apparatus of claim 26, further comprising a means for alarming, the means for alarming being integral with the means for processing, and the means for alarming being configured to selectively issue an alarm based on the difference value.

30. The apparatus of claim 29, wherein the means for processing is further trained to compute a current threshold value on the basis of the predicted flow volume and the actual flow volume and to periodically update the current threshold value, and wherein the means for alarming is configured to issue an alarm when the actual flow volume is less than the current threshold value.

31. The apparatus of claim 30, wherein when an alarm is issued by the means for alarming, the first means for monitoring is configured to communicate the alarm.

32. The apparatus of claim 31, wherein the first means for monitoring is configured to communicate the alarm via at least one of a cellular telephone means, a land line telephone means, a pager, an electronic mail means, and an Internet means.

33. The apparatus of claim 26, wherein the means for processing is integral with the first means for monitoring.

34. The apparatus of claim 26, wherein the means for processing is integral with the means for computing.

35. The apparatus of claim 26, wherein the first means for monitoring is further operative to detect data representative of flow velocity and depth, and to validate the data representative of flow velocity and depth.

36. The apparatus of claim 26, further comprising a means for detecting a quantity of rain at a location during a period of time.

37. The apparatus of claim 36, wherein the means for detecting a quantity of rain includes at least one of a rain gauge, a weather service, and a weather web site.

38. The apparatus of claim 26, wherein the mean for computing is trained to predict at least one of an anticipated flow velocity, an anticipated depth, and an anticipated flow volume of the fluid substance at a second location.

39. A storage medium for storing software for monitoring and analyzing flow in a sewer system, the sewer system including a monitoring assembly, the monitoring assembly

including at least one sensor configured to detect data representative of actual flow volume in a first location, the software being computer-readable, wherein the software includes instructions for causing a first computer to:

store the data representative of actual flow volume in a memory;

maintain, in the memory, previously stored data representative of previous flow volumes;

determine a predicted flow volume, wherein the predicted flow volume is dependent upon data selected from the previously stored data and a day and time, wherein the day and time each correspond to both the data selected from the previously stored data and the data representative of actual flow volume; and

compare the actual flow volume with the predicted flow volume to yield a difference value.

40. The storage medium of claim 39, wherein the difference value exceeds a predetermined variance value, and the software further includes instructions for causing the first computer to issue a flow loss notification.

41. The storage medium of claim 40, wherein the software further includes instructions for causing the first computer to communicate the flow loss notification by at least one of a cellular telephone means, a land line telephone means, a pager, an electronic mail means, and an Internet means.

42. The storage medium of claim 39, wherein the difference value is equal to or less than a predetermined variance value, and the software further includes instructions for causing the first computer to store the actual flow volume in the memory as stored calibration data.

43. The storage medium of claim 39, wherein the at least one sensor configured to detect data representative of actual flow volume in a first location includes at least one sensor configured to detect data representative of flow velocity and data representative of depth, and the software further includes instructions for causing the first computer to:

calculate the data representative of actual flow volume using the data representative of flow velocity and the data representative of depth; and

transmit at least one of the data representative of flow velocity, data representative of depth, and data representative of actual flow volume over a data network to a second computer.

44. The storage medium of claim 39, wherein the data representative of actual flow volume includes data representative of rolling average flow volume.

45. The storage medium of claim 39, wherein the data representative of actual flow volume includes at least one of flow velocity data and depth data.

46. The storage medium of claim 39, wherein at least one sensor configured to detect data representative of actual flow volume in a first location includes at least one sensor configured to detect data representative of flow velocity and data representative of depth, and the software further includes instructions for causing the first computer to:

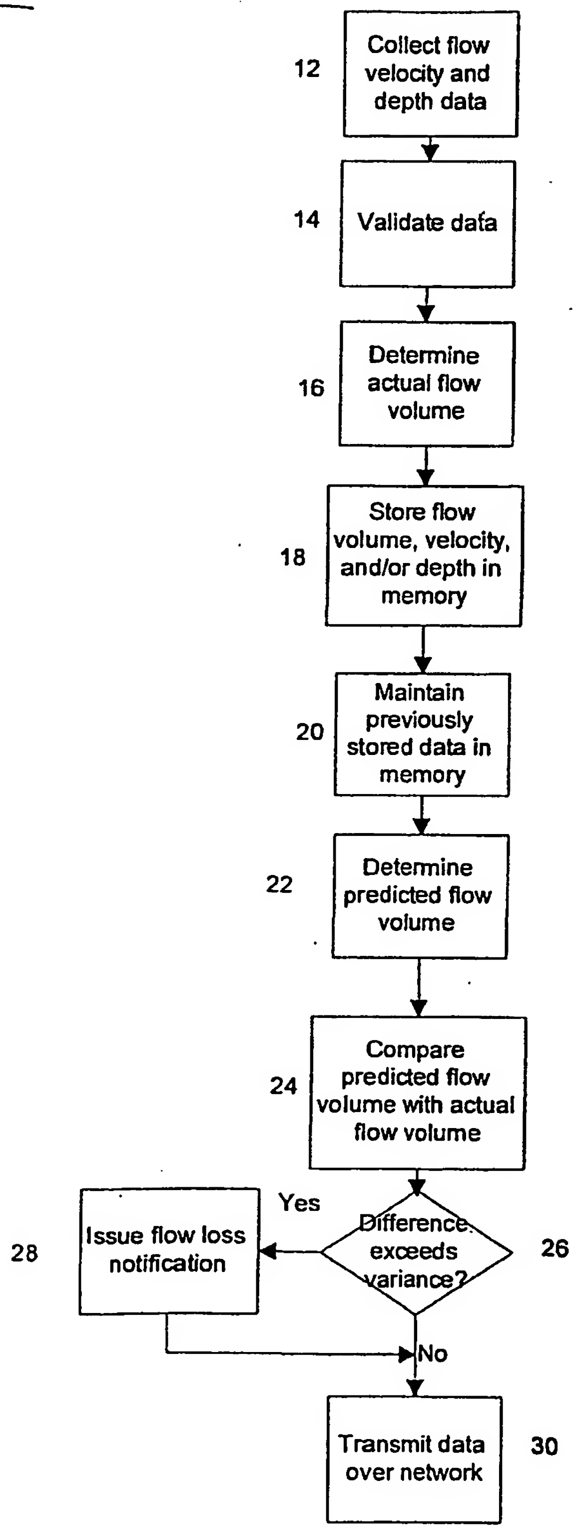
calculate the data representative of actual flow volume using the data representative of flow velocity and the data representative of depth; and

validate the data representative of flow velocity and the data representative of depth.

47. The storage medium of claim 39, wherein the predicted flow volume is further dependent upon additional data selected from the previously stored data, the additional data corresponding to a rain event.

100

FIG. 1


12
Collect flow velocity and depth data
14
Validate data
16
Determine actual flow volume
18
Store flow volume, velocity, and/or depth in memory
20
Maintain previously stored data in memory
22
Determine predicted flow volume
24
Compare predicted flow volume with actual flow volume
26
Difference exceeds variance?
Yes
28
Issue flow loss notification
No
30
Transmit data over network

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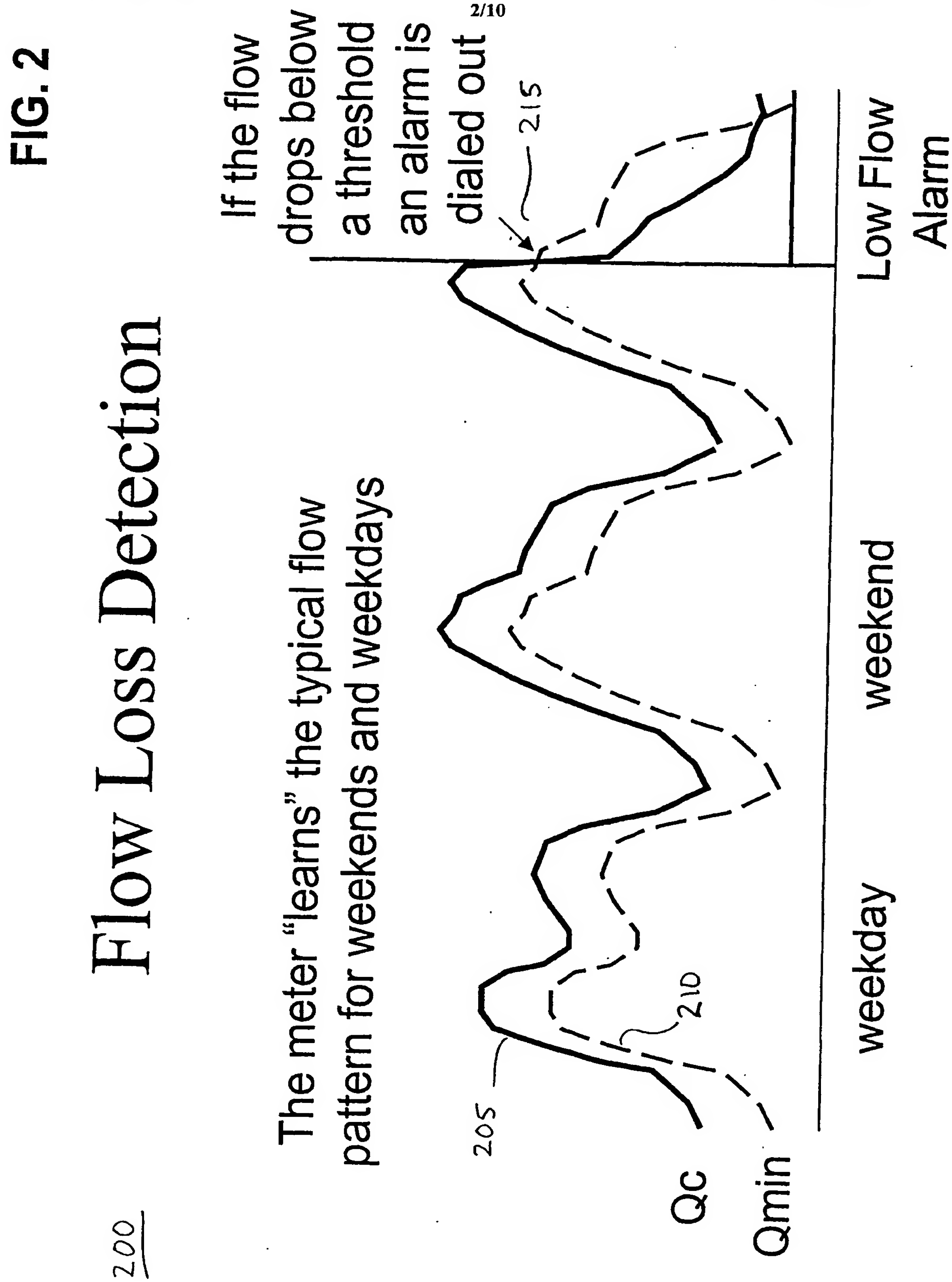


FIG. 3

Wet Weather Performance

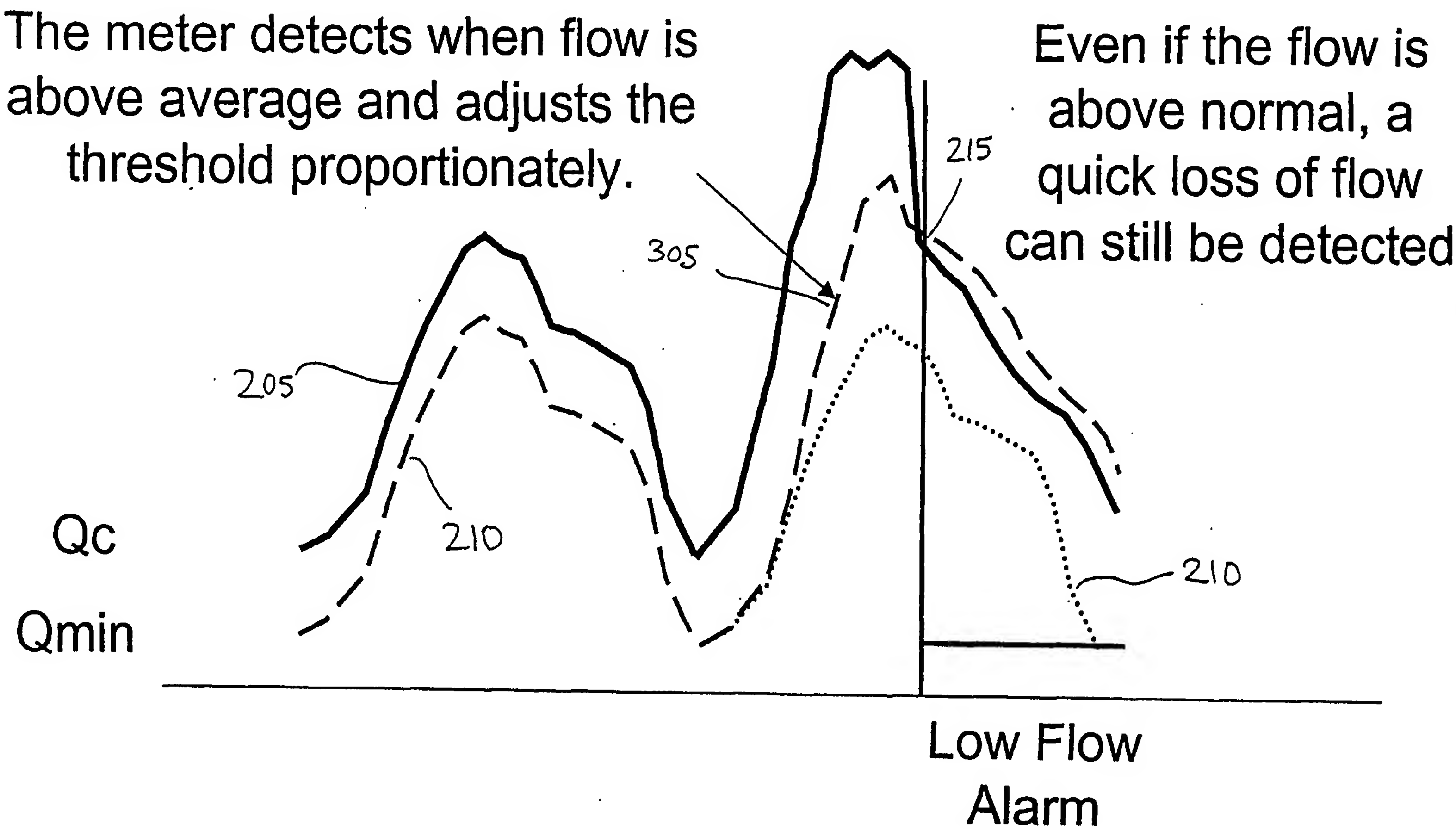


FIG. 4

Pump Stations or Industrial Flows

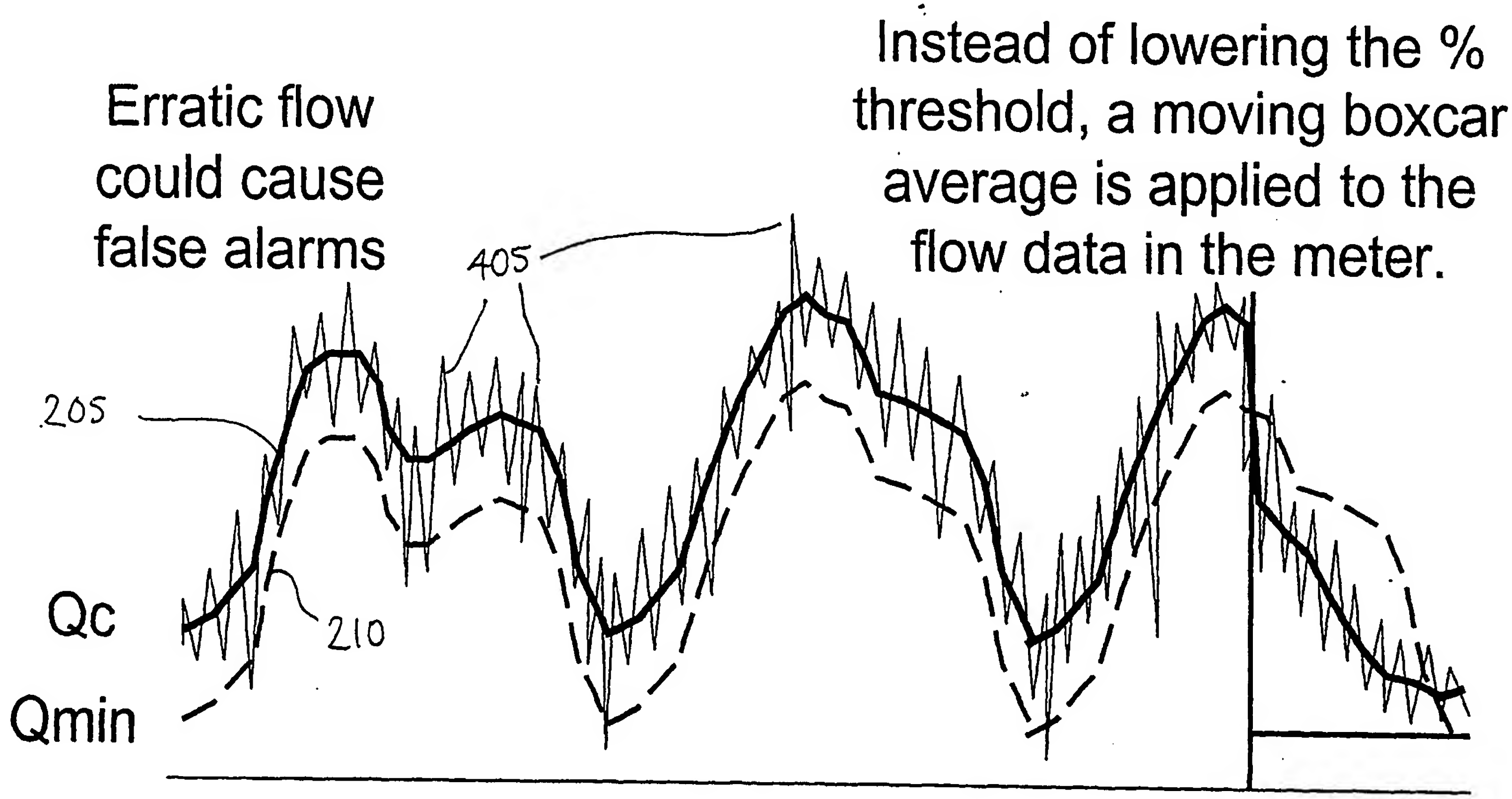
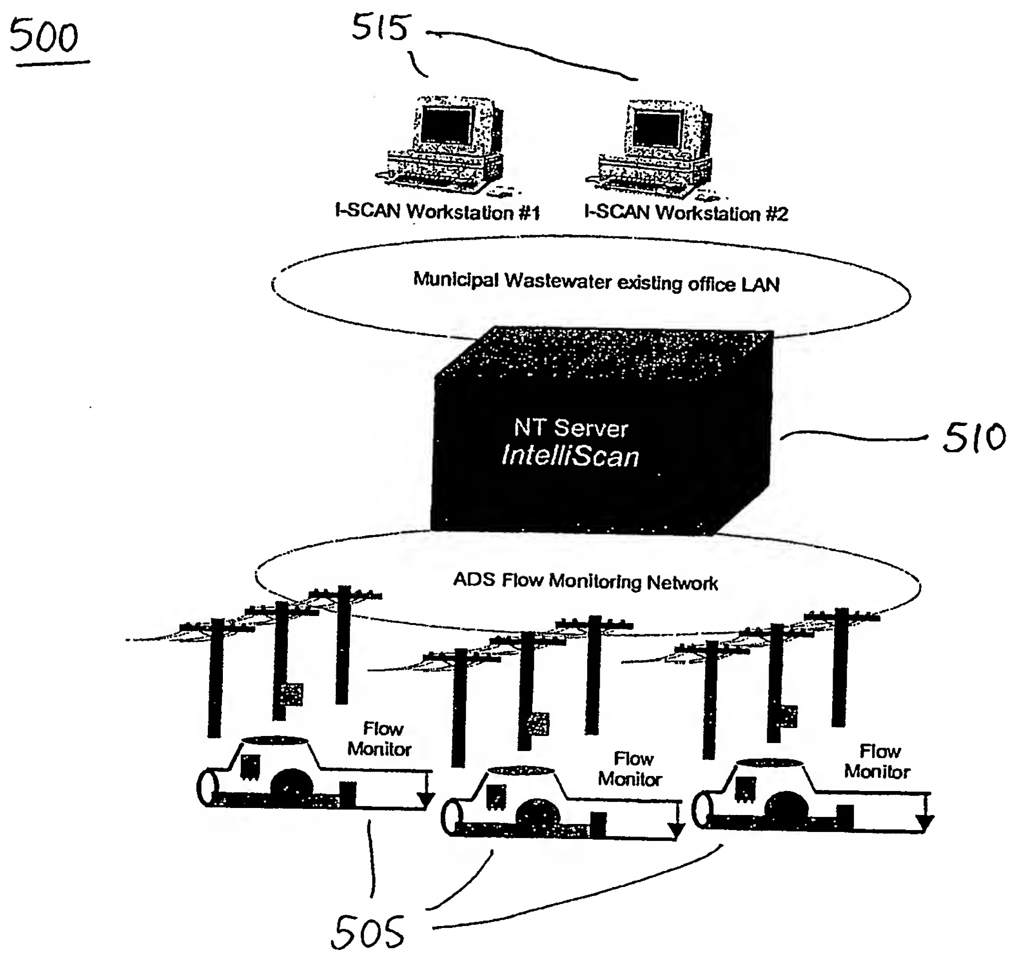


FIG. 5


500
515
I-SCAN Workstation #1
I-SCAN Workstation #2
Municipal Wastewater existing office LAN
NT Server
IntelliScan
510
ADS Flow Monitoring Network
Flow Monitor
Flow Monitor
Flow Monitor
505

600

FIG. 6

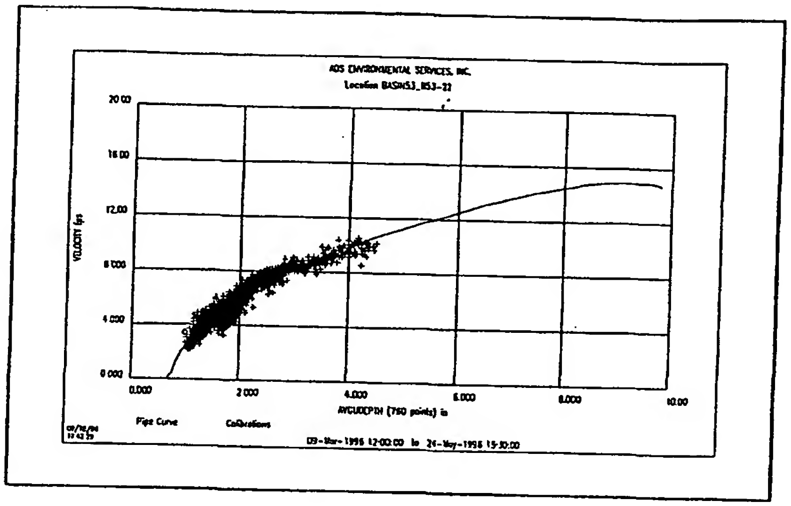
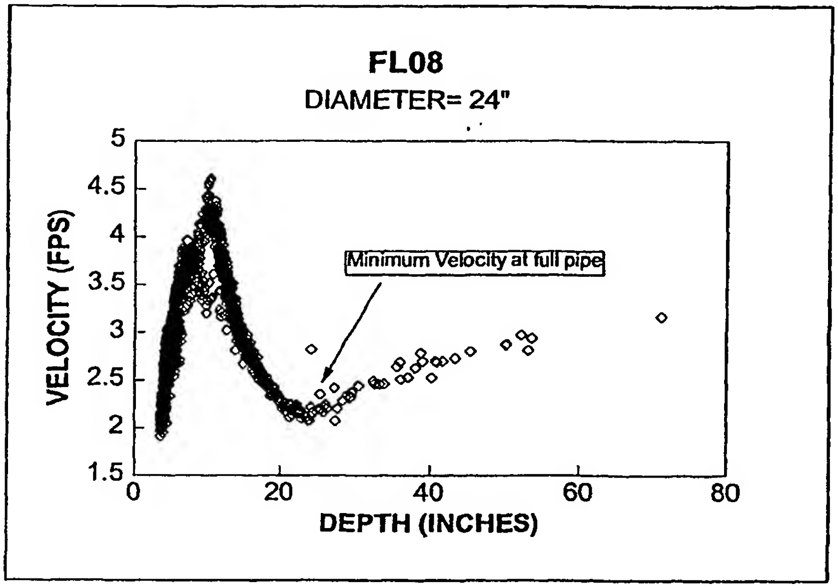

ADS ENVIRONMENTAL SERVICES, INC.
Location BASINS3_BS3-22
VELOCITY fps
20.00
16.00
12.00
8.000
4.000
0.000
0.000
2.000
4.000
6.000
8.000
10.00
AVGUDEPTH (760 points) in
Pipe Curve
Calibrations
09-Mar-1998 12:00:00 to 24-May-1998 15:30:00

FIG. 7

700


FL08
DIAMETER= 24"
VELOCITY (FPS)
DEPTH (INCHES)
Minimum Velocity at full pipe
5
4.5
4
3.5
3
2.5
2
1.5
0
20
40
60
80

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800

FIG. 8

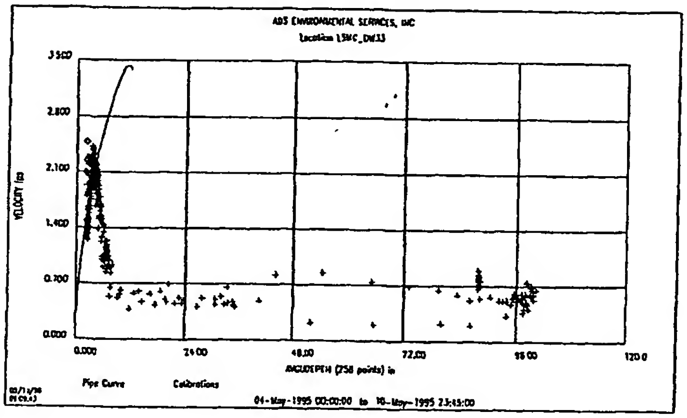

FIG. 9

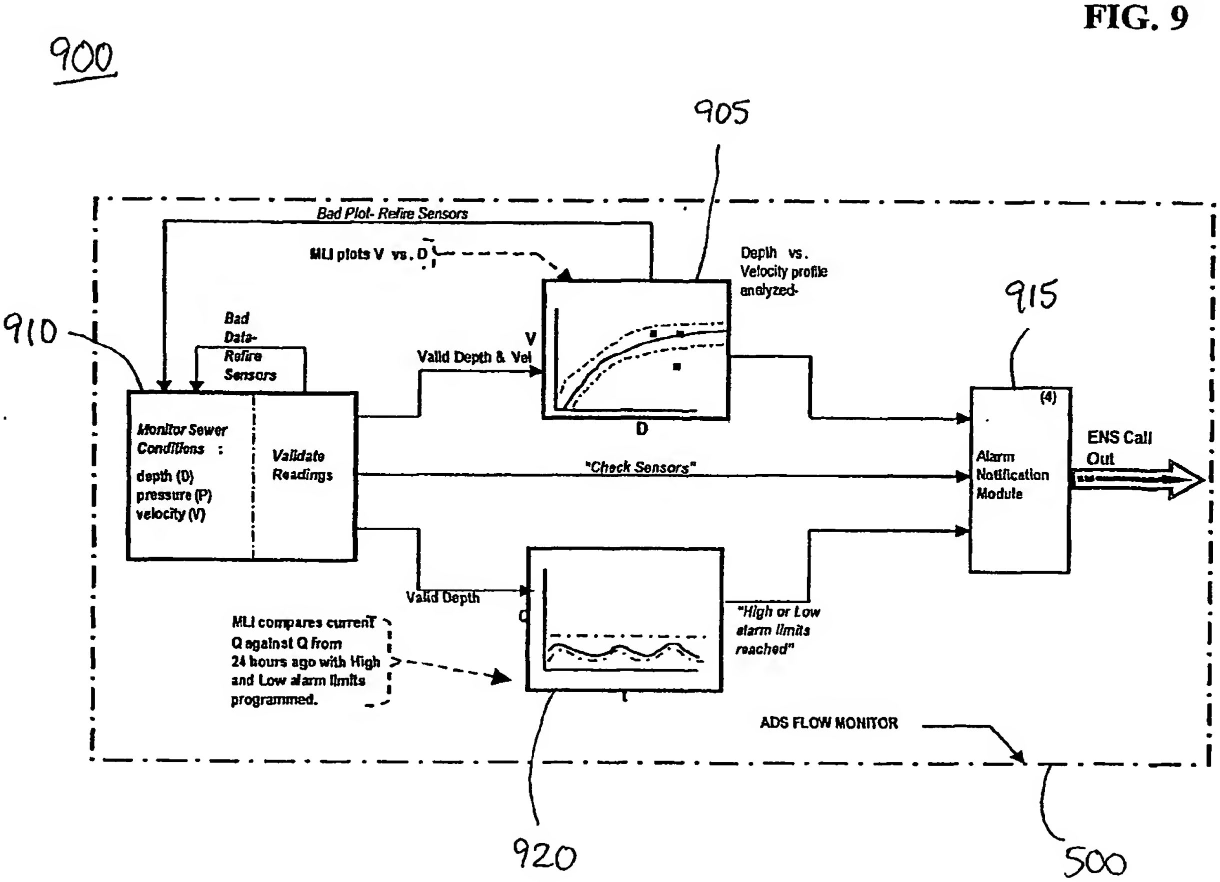

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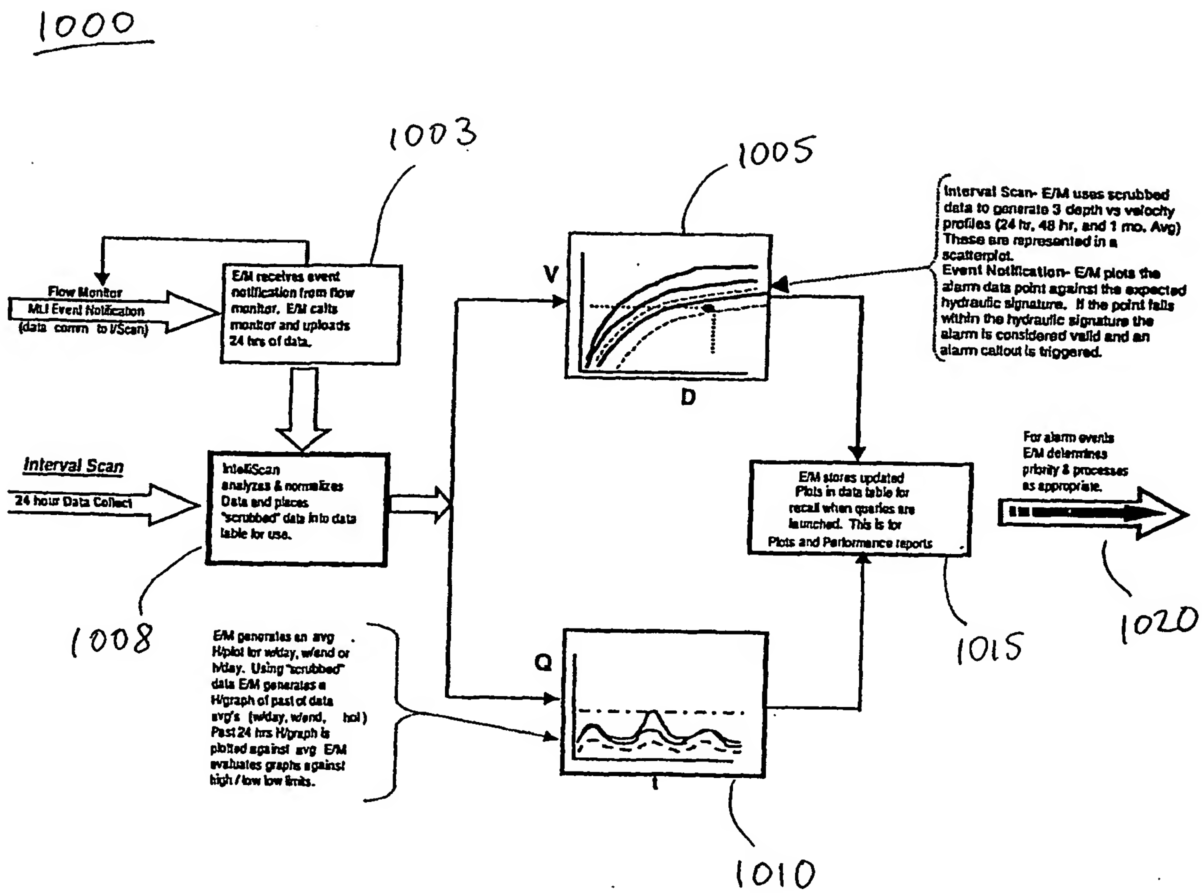
FIG. 10



BEST AVAILABLE COPY